Functional textiles in hospital interiors

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DISSERTATION SUBMITTED 2015

AALBORG UNIVERSITY
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AUTHOR CV

Jeppe Emil Mogensen, b. 1985, is educated civil engineer, specialised in architecture (M.Sc. Eng. in Architecture) from Aalborg University in 2011. In his master project, he worked with hospital architecture, and proposed a new design concept and idea for a dayroom at the new hospital planned in Skejby, Aarhus. Departing from this master thesis, a deep interest in hospital design and architecture has developed, and has now resulted in the submission of a PhD thesis, focusing particularly on the use of functional textiles in hospital interiors. The PhD project is the result of a collaboration between Aalborg University, Department of Civil Engineering and VIA University College, VIA Design, where Jeppe has worked close together with engineers and designers in the field of smart and functional textiles. Jeppe has through his career balanced technical and aesthetic aspects of architecture and design, and this holistic and integrated approach has also provided the foundation for the research in his PhD thesis.

During the past three years, Jeppe has been teaching and supervising bachelor and master students at Aalborg University and VIA University College, and he has disseminated the knowledge of his PhD research in the creative and technical educations at VIA Design in Herning. Additionally, Jeppe has presented his research in a range of international conferences, and has published peer-reviewed papers at conferences and in scholarly journals. A list of recent publications can be found at: http://person-profil.aau.dk/116793

Mandatory Page

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Paper 5:
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This thesis has been submitted for assessment in partial fulfillment of the PhD degree. The thesis is based on the submitted or published scientific papers which are listed above. Parts of the papers are used directly or indirectly in the extended summary of the thesis. As part of the assessment, co-author statements have been made available to the assessment committee and are also available at the Faculty. The thesis is not in its present form acceptable for open publication but only in limited and closed circulation as copyright may not be ensured.

ABSTRACT

This PhD thesis explores the possibilities and design qualities of using functional textiles in the interior of hospital environments, and is the result of a three-year collaboration between Aalborg University, Department of Civil Engineering, and VIA University College, VIA Design. The thesis consists of a collection of 5 peer-reviewed papers, and an extended summary.

The project is overall related to the construction of new Danish hospitals, where the design concept *healing architecture* is introduced in a national context, representing the vision of a promoted healing process of hospitalised patients supported by design related influence. Past research studies provides evidence that the physical environments affect the patients' level of stress and influence their process of recovery and healing. However, although research in this field of hospital design has increased substantially in recent years, knowledge on the use of interior materials and textiles are still rather limited.
Contemporary hospital design has been widely criticised of being too institutional and clinical, and one of the main reasons for this experience may be related to the use of 'cold', hard-surfaced materials of plastic, vinyl and steel. These materials also dominate the new hospitals, designed and constructed these years, and despite the increased focus on the design concept healing architecture, the rational requirements of efficient cleaning and maintenance still seems to direct the interior design of hospital environments. However, in architectural and design related theory, materials are linked closely to the perceived atmosphere of spaces, and a better awareness on the aesthetic material qualities are considered needed to accommodate the visions of healing architecture.

Traditional textiles that earlier have been used in hospital interiors, have in previous studies been associated with increased risks of hospital acquired infections, and in hospitals today they are therefore replaced by plastic-coated upholsteries. These plastic materials may improve the cleaning efficiency, but it often side-effects the aesthetic experience and contribute to the perception of a clinical and institutional environment. The hygienic concerns of hospital interiors are naturally essential, but the field of *functional textiles* has in recent years emerged rapidly. New types of textiles can thus be designed with added functionalities that for instance provide the textiles with a hygiene-improving surface; properties that might enable the use of textiles in future hospital interiors.

Knowledge on the use of these functional textiles in hospital interiors is still limited, but concerned with the immediate potentials, the purpose of this PhD project has been to explore the possibilities and design qualities of using these materials in hospital interior design. Relating to both technical and aesthetic aspects of using functional textiles in hospitals, the project seeks to integrate these aspects, departing from the overall research question:

What are the technical possibilities of using functional textiles in Danish hospital interiors, and how can interior textiles contribute with aesthetic qualities that promote the patients' experience of the hospital interior?

The research question is explored in two main parts of the project, relating to the technical and aesthetic qualities, respectively.
Through empirical and theoretical background studies in the technical and aesthetic domains of the project, a range of hypotheses are defined for testing in experimental studies. The technical background studies introduce the field of functional textiles and define the requirements and demands for the use of textiles in hospital interiors. The technical experimental studies then demonstrate that it is possible to use the functional textiles and comply with the national Danish standards and guidelines for hospital cleaning and disinfection, if new logistic processes are developed.
In the aesthetic part of the project, the aesthetic qualities of using textiles in hospital interiors are explored and accentuated through a theoretical framework, related to the concept of atmospheres. Familiarity and tactility are here deduced as two main design qualities that may improve the patients' experience of the hospital interior, and in the experimental studies these aesthetic qualities are contextualised in empirical studies conducted at two Danish hospitals.

Through these different studies, the PhD thesis addresses the technical and aesthetic design qualities of using functional textiles in hospital interiors, and summarises this exploratory approach by proposing an integrated model that accentuates these design qualities. Based on the findings of this project, additional research studies are proposed to further progress the development within the field of functional textiles for future hospitals.

RESUMÉ

Denne Ph.d. afhandling undersøger mulighederne og designkvaliteterne ved at bruge funktionelle tekstiler i hospitalsindretninger, og er resultatet af 3 års samarbejde mellem Aalborg Universitet, Institut for Byggeri og Anlæg og VIA University College, VIA Design. Afhandlingen består af en artikelsamling med 5 peer-reviewed artikler og et udvidet sammendrag (extended summary).

Ph.d. projektet er overordnet relateret til opførslen af nye danske super-sygehuse, hvor design konceptet *helende arkitektur* er introduceret. Konceptet repræsenterer visionen om en hurtigere helingsproces for indlagte patienter, understøttet af design relaterede faktorer. Tidligere forskningsstudier har påvist, at det fysiske miljø har en indflydelse på patienters stressniveau, og dermed har en betydning for deres helingsproces. Selvom omfanget af forskningen indenfor dette område af hospitalsdesign er steget markant de seneste år, er der dog stadig begrænset viden om brugen af materialer og indretningstekstiler i hospitalssammenhænge.
Nuværende hospitalsdesign er ofte blevet kritiseret for at være for klinisk og institutionel, og en af grundene til dette kan hænge sammen med brugen af 'kolde', hårde materialer som plastik, vinyl og stål. Disse materialer dominerer også indretningen af de nye hospitaler, der designes i disse år, og trods et stigende fokus på design konceptet helende arkitektur, er de rationelle krav til effektiv rengøring og vedligehold stadig styrende for hospitalernes indretning. I arkitektur og design teori, er materialer dog koblet tæt til den oplevede atmosfære, og en større bevidsthed om materialers kvaliteter vurderes umiddelbart nødvendige for at imødekomme visionerne for helende arkitektur.

Traditionelle tekstiler, der tidligere blev brugt i hospitalsindretningen, er i tidligere studier blevet kædet sammen med risikoen for hospitalsinfektioner, og i danske hospitaler erstattes møbeltekstilerne derfor ofte med betræk af plastik. Selvom plastikmaterialet forbedrer rengøringseffektiviteten, har det samtidig en negativ indflydelse på den æstetiske oplevelse af indretningen og fremmer den kliniske og institutionelle atmosfære. Hygiejnen på hospitalet er naturligvis af afgørende betydning, men indenfor de senere år, er der udviklet en række nye materialer indenfor feltet af *funktionelle tekstiler*. Nye typer tekstiler kan således udvikles og designes med nye funktionaliteter, der eksempelvis kan give tekstilerne en hygiejnisk overflade, og dermed egenskaber, der potentielt gør tekstilerne velegnede til indretningen af fremtidens hospitaler.

Viden om brugen af disse funktionelle tekstiler i hospitalsindretningen er stadig begrænset, men i forhold til det umiddelbare potentiale, er det dette Ph.d. projekts formål at undersøge mulighederne og designkvaliteterne ved at anvende disse materialer i indretningen af hospitalerne. Projektet relateres både til de tekniske og æstetiske design kvaliteter, og vil gennem projektet søge at integrere disse aspekter baseret på den overordnede problemformulering:

Hvad er de tekniske muligheder for at bruge funktionelle tekstiler i indretningen af danske hospitaler, og hvordan kan indretningstekstiler bidrage med æstetiske kvaliteter, der kan forbedre patienternes oplevelse af hospitalsindretningen?

Problemformulering adresseres gennem to overordnede projektdele, der relateres til henholdsvis de tekniske og æstetiske kvaliteter.
Gennem empiriske og teoretiske baggrundsstudier i de tekniske og æstetiske domæner, defineres en række hypoteser, der efterfølgende afprøves i eksperimenterende studier. De tekniske baggrundsstudier introducerer således feltet af funktionelle tekstiler, og fremhæver de krav og kriterier som tekstilerne skal opfylde i hospitalskonteksten. De eksperimentere studier efterviser derefter, at det er muligt at bruge tekstilerne og opfylde de danske standarder og anbefalinger for rengøring og desinfektion, hvis nye logistiske processer bliver udviklet.
I den æstetiske del af projektet, undersøges og fremhæves de æstetiske kvaliteter gennem et teoretisk rammeværk relateret til atmosfærebegrebet. I de æstetiske baggrundsstudier udledes det familiære og taktile som to centrale designkvaliteter, der kan forbedre patienternes oplevelse af hospitalsinteriøret, og i de eksperimenterende studier relateres disse kvaliteter til patientoplevelser gennem empiriske studier på to danske hospitaler.

Gennem de forskellige studier adresserer afhandlingen de tekniske og æstetiske designkvaliteter ved at bruge funktionelle tekstiler i hospitalsindretningen, og disse kvaliteter fremhæves og opsummeres afslutningsvis i en integreret model. Med udgangspunkt i projektets resultater, foreslås der efterfølgende nye forskningsstudier, der kan fortsætte udviklingen i feltet af funktionelle tekstiler til fremtidens hospitaler.

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PREFACE

A recent article from the Danish newspaper Politiken (11.8.2015) addresses focus on culture and art as an active and effective mean to strengthen chronic patients' health and well-being (Hjortshøj 2015). The environment can have an influence on the patients' healing process, and in the article the consultant doctor Per Thorgaard from Aalborg University Hospital states that:

> *"By including art and culture during therapy you think holistic and allow the patient to use their own resources to come to terms with their illness or use them to improve their rehabilitation [...] Culture is an indispensable part of life – also for the sick." (Thorgaard 2015, cited in Hjortshøj 2015) [Translated by author].*

Scientific studies have repeatedly demonstrated that anxiety, depression, stress, blood pressure, etc. are affected by the physical surroundings. Both in terms of art and culture, which again is on the agenda, but also in regards to interior design and architecture in hospitals and the health care sector in general.
This PhD is not about art or cultural offers per se, but it is about the interior of hospital spaces, which have a strong, but often neglected, potential in improving the patients' experiences.
As one of the first cross-disciplinary research studies, this PhD project addresses focus on the use of functional textiles in hospital interiors as a mean to support both the technical requirements for hospital cleaning and the aesthetic needs of hospitalised patients. Today the physical surroundings of hospitals are often criticised of being too institutional and clinical in their physical appearance, and as this project will propose, functional textiles in hospital interiors may contribute with a new material alternative to contrast the traditional hard-surfaced materials used in contemporary hospitals. From a design perspective, the hospital interiors will be improved by a design that not only satisfies the rational and functional aspects of efficient hygiene and cleaning, but also includes the emotional values of design experiences to provide a more accommodating atmosphere. The design of the modern hospitals should thus be balanced with greater considerations and respect for the patients' aesthetic experience, and to integrate these aspects, new visionary design strategies and innovative materials are needed.
Hospital design is considered one of the most complex tasks of architecture, but at the same time a very substantial assignment influencing vulnerable patients and emotionally exposed visitors. To create an accommodating and inspiring architectural environment within the health care sector's rational regulations and requirements is defining a challenging task; and to discover new creative ways of dealing with this complexity is what I find particularly interesting in regards to hospital design.
Educated as civil engineer specialised in architecture from the Department of Architecture and Design at Aalborg University, my background relates to both the technical and aesthetic dimensions of architecture and design, and this integrated approach

has also inspired this project. To unfold and explore the qualities of using functional textiles from a broad perspective, the project relates to the technical aspects of applying textiles in the hospital environment in terms of hygiene concerns and material technology, but also the aesthetic aspects of patient experiences and material qualities have been addressed.
To conduct a PhD study is an inspiring and sometimes challenging process, and through the past three years, I have been greatly assisted by many different people, and without their help, the project would not have reached its final destination of submission.
First of all, I would like to express my greatest gratitude to my supervisors Anna Marie Fisker and Søren Bolvig Poulsen, for all their advice, comments, support and enormous effort in guiding me throughout this project. Also my colleagues at VIA Design in Herning deservers my thankfulness in realising this project: Poul-Erik Jørgensen for being an invaluable discussion partner and inspiring supervisor in my launching inquiry into the field of smart and functional textiles; Hanne Troels Jensen and Anne Mette Zachariassen for believing in the initiation of project; and all my other co-workers in Herning, who have provided a colourful and inspiring work environment to facilitate the design-based research process. I also want to thank my colleagues at the Department of Civil Engineering for great collaboration, and especially head of department Peter Frigaard and head of section Lars Damkilde for hosting and supporting the project. The PhD project have received special funding from Fabrikant Christian F. Madsens Fond, and I am very grateful for this support.
In the project, a range of design experiments have been conducted at Danish hospitals, and I would like to take the opportunity to thank the staff at the Service Department at Hospital Vendsyssel, Hjørring and the staff at the Nephrology Department at Odense University Hospital for participating with great enthusiasm in the experimental parts of the project. In that regard also a special thank you, to the Health Innovation Centre of Southern Denmark, and especially Kristine Kjærsig and Louise Linaa for a very great collaboration on the design experiment in Odense. I hope our collaboration will continue in future projects.
Finally, I would like to thank my family for their support through the past three years. Inger Lise, thank you for being nearly as enthusiastic about the project as I have been, and for being a great help in relating all my ideas and observations to the everyday practice at the hospital. Your significant effort as a professional, kind and caring doctor has inspired me more than you probably know, and have motivated me to do my best to contribute in improving the physical environment for the patients at your work place.

Hospital design is an important task for architects and designers, and there is nothing to loose by designing hospitals that recognise the importance of the patients' experience of the physical environment, and potentially support the healing process. Thus, it is with a humble hope of a potential contribution to such improved healing processes that this PhD project is initiated, which in the long term hopefully may influence both practice and policy and provide a more patient-friendly interior of future hospitals.

Jeppe Emil Mogensen, Aalborg, September 2015

INTRODUCTION

Denmark is in these years constructing new hospitals throughout the country, and spending more than 40 billion DKK, the hospital construction process is the largest in the Danish history. Intending to improve the quality of the national health care system, the new projects are designed and planned with patient-centeredness as a main focus area. The patients' needs and experiences of the environment are basis of the general planning, envisioning that architecture and design contribute as promoters for the patients' healing process (Danish Hospital Construction 2013). The new hospitals are planned for completion and operation within the next 5-15 years, and the need for the new physical structures are evident.

The health care design researcher, Roger S. Ulrich, who since the 1980's have studied how architecture and design affect the patients' healing process, introduces his comprehensive review in 2008 by stating that a visit to a U.S. hospital is dangerous and stressful for the patients (Ulrich et al. 2008). Not only because of the risk of hospital-acquired infections and medical errors, but also because the physical environment is not supporting the patients' healing process. Also in an European context, Dutch professor in architecture, urbanism and health Cor Wagenaar refers to the hospitals as 'build catastrophes', as he emphasise that the hospitals are: *"anonymous institutional complexes run by vast bureaucracies, and totally unfit for the purpose they have been designed for. They are hardly ever functional, and instead of making patients feel at home, they produce stress and anxiety."* (Wagenaar 2006, p. 11).

Similar experiences may also be regarded from a Danish perspective. In the book "Sansernes hospital" [Hospital of the senses], architect Kim Dirckinck-Holmfeld and doctor Lars Heslet, characterize the current Danish hospitals as 'machines for treatment', and sets out how the evidence-based focus of the medical profession has dictated the architecture of the current hospitals, built in the 1960's and 1970's (Dirckinck-Holmfeld et al. 2007). With the increased focus on medical treatment, the patients were reduced to physical objects, and the emotional aspects of the holistic treatment process were neglected (ibid).

However, with the construction of new hospitals, the architectural and design-related influence on the patients' experience and potential healing process has regained its priority. Promoted by research that establish an evidence-based link between design aspects and patient outcomes (Frandsen et al. 2009, Horsburgh Jr. 1995, Ulrich et al. 2008, Ulrich et al. 2004), awareness on the role of design in the healing process has been raised (Vindum et al. 2011, Vindum 2011). Synthesized in the design concept 'healing architecture', the vision of an improved healing process supported by design and architecture has been defined and established (Frandsen et al. 2009), and the patients' experiences and concerns are again prioritised as an important parameter together with the medical treatment (Dirckinck-Holmfeld et al. 2007). It is essentially not

the architecture or design alone that heal the patient, but research concordantly demonstrate that there is a link between accommodating hospital architecture and improved healing processes (Dirckinck-Holmfeld et al. 2007, Ulrich et al. 2008). The physical environment affects the healing process, and in the comprehensive review on healing architecture by Frandsen et al. (2009), more than 200 research studies were identified and included in the review. The main focus in most of these studies directed the design aspects of daylight, nature, acoustics, etc., while none of the studies focused on the use of materials in hospital interiors.

HOSPITAL INTERIOR DESIGN

Despite the increased focus on healing architecture, which evidently has improved the patients' hospital experience, the pictures (ill. 1.1), taken from the books ”Hospital Architecture” (Nickl, Nickl-Weller 2007, Nickl-Weller, Nickl 2013), call attention to the lack of material awareness in hospital interiors.

Ill. 1.1 Pictures of recently built hospitals in Europe. From the books "Hospital Architecture" by Nickl-Weller & Nickl (2007 & 2013). Above: St. Mary Hospital, Ludwigshafen (built 2006). Opposite page, above: Clinique Monet, Champigny (built 2011); Opposite page, middle: District Clinic, Esslingen (built 2012). Opposite page, lower: Medical Clinic, Tübingen (built 2007).


KASSE - Kochen, Ess
Snacks

Although the hospital environments are bright and even nature-inspired, the hard-surfaced interior materials of gypsum, vinyl, steel and plastic are inevitably imbuing an institutional atmosphere, which seem to oppose the fundamental visions of healing architecture.
If the physical environments should facilitate and support the patients' inner healing process, the use of interior materials in hospitals would probably benefit from a revaluation.

Ill 1.2 Pictures of a seating situation at Lund University Hospital (left), and Michelin-starred Restaurant Geranium, Copenhagen (right).

The two pictures above (ill. 1.2) both illustrate a seating situation, and although the basic function is the same, there is an immense difference in the experienced atmosphere of the hospital and restaurant settings. Admittedly, the foundations are essentially different, as the restaurant have a greater liberty of action in terms of finances and code of practices, but still the two pictures clearly emphasise how materials affect the experience of interiors. In architectural and design related theory, materials are linked closely to the perceived atmosphere of spaces (Böhme 1993, Zumthor 2006, Pallasmaa 2013), and in the examples above, the textile upholstery changes the interior extensively. The same effect could possibly improve the institutional perception of contemporary hospitals as well, which will be addressed through this PhD thesis.

TEXTILES IN HOSPITAL INTERIORS – HYGIENIC CONCERNS

The aesthetic experience of hospital interiors have a great potential, but the hygiene concerns are evidently important in a hospital environment as well. In 2006 a Danish study showed that app. 10 % of all patients acquired a hospital infection (HAI) during their hospitalisation (Leth, Møller 2006). In an effort to reduce this high risk of infections, a range of different initiatives and campaigns were commenced, and the focus on interior materials as a cause of indirect contamination was also addressed. In the "National Infection Hygiene Guidelines on Health Care Constructions and Renovation", published by Statens Serum Institut [The National Serum Institute], it is emphasised that the risk of infections are reduced if the interior surfaces inhibit the growth of bacteria or are easy to clean (Statens Serum Institut 2013). As most groups of patients with a compromised immune system are in higher risk of new infections, it is essential that the hospital environment maintain a very high level of hygiene. In that regard, the traditional textiles that earlier were used in the interior for upholstery, curtains, etc. have been defined as potential bacteria reservoirs (Gao, Cranston 2008, Fijan, Turk 2012, Morsing, Klamer 2011), and in scientific studies bacteria have been measured to survive on the textile surfaces for up to several weeks (Noskin et al. 2000, Lankford et al. 2006, Huang et al. 2006). If the textiles should be used in the hospital interior, they should therefore be laundered regularly (Statens Serum Institut 2013, Danish Standard, DS2451-8:2013). Through interviews with actors from the service and cleaning department at Danish hospitals, it however becomes evident that the laundering of traditional textiles, especially for upholsteries, is expensive and inappropriate to process (presented in paper A). The upholsteries need to be disassembled from the chair and sent to laundering, and during this process the ward is often lacking the chair in the interior setting. In order to optimise the efficiency of the hospital cleaning process, the traditional textiles are therefore being phased out of the hospital environment, and are replaced by plastic coated upholsteries of polyurethane, as illustrated below (ill 1.3).

Ill. 1.3 Armchair from the newly built Hospital Vendsyssel, Hjørring, Denmark. The chair is the result of a primary focus on rational requirements of efficient cleaning, and the lacking aesthetic qualities of the chair contribute to the experience of an institutional atmosphere of the interior.

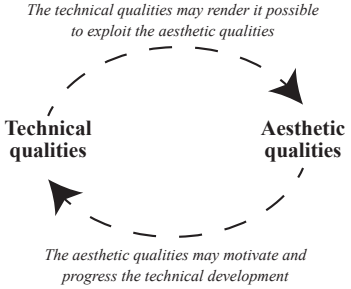
In most hospitals today, the rational requirements of efficient cleaning, thus seem to be the governing basis for interior design decisions, side-effecting the aesthetic experiences. The picture of the hospital chair illustrates the result, which correspond well with the previous pictures of institutional hospital interiors (ill 1.1, p. 18).
The hygiene concerns of hospital interiors are naturally essential, but the field of *functional textiles* has in recent years emerged rapidly. New types of textiles can thus be designed with added functionalities that for instance provide the textiles with an antibacterial or water- and dirt repellent surface; properties that might enable the use and re-application of textiles in future hospital interiors.

RESEARCH APPROACH

So far knowledge on the application of functional textiles in hospital interiors is limited, but concerned with the immediate potentials, the project will explore these issues further. Relating to both technical and aesthetic aspects of using textiles in hospitals, the project thus departs from the assumption and initiating hypotheses that interior textiles may promote the patients' experience of the hospital interior, and that functional textiles may comply with the standards of hygiene in the hospital context.
Combining the innovative technologies with the aesthetic qualities of textiles, the overall purpose of the project has been to further unfold these initiating hypotheses by exploring and accentuating the possibilities and qualities of using functional textiles in the interior of future hospitals.

The project is one of the first exploratory studies in the field of functional textiles in hospital interiors, and to provide a broad perspective on this area of concern, the project thus focuses on two integrated aspects. The precondition for using textiles in future hospital interiors is fundamentally that they can comply with the *technical* demands of hospital hygiene, and that the *aesthetic* qualities of the textiles will have a positive influence on the patients' experience of the interior design. If the textiles cannot maintain the necessary hygiene level, the use of the materials is not justifiable; and if the textiles do not improve the patients' experience, the plastic materials may equally well be used in future hospitals.
The aesthetic and technical aspects of the project are thus of equal standing, and the relationship of the aspects are intertwined and depends on each other. The relation between the technical and aesthetic aspects is illustrated in fig. 1.4, exemplifying that the technical qualities are requisite for hospital application, and that the aesthetic qualities are essential for motivating the technical development and application. This motivation may also relate to certain business aspects in terms of costs of purchasing and operation, as well as savings associated with potential shortened hospitalisations, but to focus the project, the business aspect will not be unfolded in this thesis.

Fig. 1.4 Integrated model - relations between the technical and aesthetic aspects



The integrated model illustrates the relation between the technical and aesthetic design qualities of textiles, which will be explored through this PhD thesis. Concerned with the strict demands for hospital hygiene, the first section of the project will relate to the technical aspects, and explore if the functional textiles can comply with current standards and guidelines for hospital infection control, and thus be used without compromising the hygiene.
After these technical concerns have been addressed (see the technical chapter), the aesthetic design qualities will be unfolded in the aesthetic project part.
Although the project is departing from the assumption and initiating hypothesis that textiles may improve the aesthetic dimension of hospital interiors, there is found no existing research that confirms this idea (see also fig. 2.9, p. 46, for results of systematic literature review). A few articles and scientific papers, however, suggest that familiar and tactile materials and textures could contribute to a less institutional and more home-like environment (Lawson, Phiri & Wells-Thorpe 2003, Carr 2011), and that textiles are preferred in favour of hard surfaced, cold materials (Caspari, Eriksson & Nåden 2011). However, these assumptions and suggestions have not yet been explored or documented through any design-based empirical studies, which is considered needed to facilitate the use of these materials in the hospital context.
The qualities of daylight, nature views, and good acoustics that are often addressed in hospital design today, are also traditionally well-known from an architectural perspective, but only when research studies established the link to 'healing architecture', were the design parameters again prioritized in hospital design (Vindum et al. 2011). Research studies have therefore provided the scope for articulating the qualities of these design aspects, and in the same way, this project will explore and accentuate the potential design qualities of functional textiles. By exploring the technical possibilities of using functional textiles in hospitals, and the aesthetic qualities of the materials, the project contributes to the field of research in hospital design, and secondly aims to provide research-based knowledge to inform the decision-makers in charge of designing the interiors of future hospitals.

RESEARCH QUESTIONS

Focus on hospital design has in recent years increased, but there is still a lack of knowledge regarding the use of textiles in hospital interiors. Both in terms of the technical possibilities of using new functional textiles, but also in regards to the aesthetic dimension of textiles that may improve the patients' experience of the hospital interiors. To broaden the field of research in hospital design, the project thus focuses particularly on the use of functional textiles in hospital interiors.
Recognising that this area of concern is cross-disciplinary and related to both technical and aesthetic dimensions, the overall research question seeks to frame this complexity by questioning:

Main research question:

> *What are the technical possibilities of using functional textiles in Danish hospital interiors, and how can interior textiles contribute with aesthetic qualities that promote the patients' experience of the hospital interior?*

To operationalise the research approach, this integrated research question is reflected in two main parts of the project, relating to the *technical* and *aesthetic* aspects, respectively.

In the technical part focus is directed on the adequate possibilities of using the materials in a Danish hospital context, and the part will particularly explore:

- Which types of functional textiles with hygiene improving properties are available, and which will be most suited for the Danish hospital context?
- Which criteria should the functional textiles fulfil in terms of hospital hygiene, relating to the Danish requirements of cleaning and disinfection?
- Can the functional textiles be cleaned and disinfected in an efficient and adequate manner?

The aesthetic part relates to the patients' experience of the hospital environment, and will specifically address:

- What are the aesthetic qualities of textiles that in regards to the current hospital context may improve the patients' experience of the hospital interior?
- How does a hospital interior based on textile objects influence the patients'

experience of the interior atmosphere?

In the project focus is directed on interior textiles, and for the clarity of the research project further limited to hospital upholsteries. Textiles may be used for curtains, upholstery, bed linen, etc., but the potential is considered most extensive in areas where the material is not used today, and where the tactile dimension may improve the patient experience. Upholsteries thus constitute an essential domain, as it may be a potentially improving contrast to the plastic materials used today. From a technical perspective, the hygienic demands are furthermore most challenging, when the patients are in direct contact with the textiles, and this challenge is considered essential to address. The results from the project, may however be related to the use of interior textiles in other areas of the hospital as well.

RESEARCH CONTRIBUTION

The overall purpose of the project is to explore and accentuate the possibilities and qualities of using functional textiles in the interior of future hospitals, and departing from the exploratory research questions, the project seeks to contribute to the field of hospital design. As there is found no existing research that explores these design qualities, the objective is to provide knowledge to an integrated model (presented in the conclusion p. 114) that accentuates the technical and aesthetic qualities of using functional textiles in hospital interiors.

With the design-based nature of the project, the contribution also seeks to influence practice, and an aspect of the study has therefore been to contribute with knowledge to inform the relevant actors in the hospital service departments and the textile industries. These actors are considered primary users of the practice-related knowledge provided through this project. The hospital service departments and related health care counsellors are key actors in the process of buying new furniture and interior elements, and this process could be benefited with new knowledge on functional textiles in the hospital environment. The results from the project could thus inform the departments and contribute with inspiration, guidance and recommendations in regards to purchasing, cleaning and environmental controls.
The textile companies in Denmark could benefit from new knowledge on functional textiles and the possibility of using these materials in the construction of new Danish hospitals. The results could inspire textile designers and developers on new market opportunities in the field of functional textiles, and provide directions for new technological innovations.

Having introduced the problem field of the project, and the overall research question and approach, I will in the following section provide a short overview of the structure of the thesis.

STRUCTURE OF THE THESIS

This PhD project constitutes a collection of five individual papers that each address different aspects related to the projects cross-disciplinary scope. To provide an overview of how these papers relate to each other and to this extended thesis summary, I will describe the overall structure of the thesis.
The project is divided in five overall chapters, including the: 1) Introduction, 2) Research methodology; 3) Technical part; 4) Aesthetic part; and 5) Conclusions and reflections.

With this description of the thesis structure, the first chapter is closing. Chapter 2 then introduce the project's 'Research methodology', which position the project in the pragmatic philosophical domain (Peirce 1931-58), and presents research-through-design (Koskinen et al. 2011, Brandt, Binder 2007, Bang et al. 2012) as the overall methodology that can facilitate the exploratory nature of the project in the cross-disciplinary field. To maintain an overview of the combined and integrated methodological approaches, the project's system of inquiry is defined, before presenting the individual methods of the studies in the technical and aesthetic project parts. Relating to the pragmatic philosophy and the research-through-design methodology, the studies are based on the process of abductive reasoning, and constitutes some background studies, which establish a range of hypotheses that are tested or explored in experimental studies.
Chapter 3 relates to the 'Technical part' of the project, and introduce the field of functional textiles in regards to the use in Danish hospital interiors. The findings of this study are also presented in paper A: *"Design Innovations and Implementation Challenges – A Case of Smart Textiles in Future Hospital Interiors"*. A section then highlights the requirements and demands that the textiles should fulfil for application in Danish hospital interiors, and based on these background studies, a range of hypotheses are defined for testing in technical experimental studies. The first experiment addresses the possibilities of cleaning functional textiles in a hospital setting, and is also presented in paper B: *"A microbiological evaluation of SiO_2 coated textiles in hospital interiors: The effect of passive coatings on the cleaning potential of interior textiles"*.
The second technical experiment, consists of three laboratory studies on cleaning, disinfection and durability of the functional textiles, and is presented in report C: *"Tekstiler til fremtidens hospitaler – rengøring og desinfektion af funktionelle tekstiler - [Textiles for future hospitals – cleaning and disinfection of functional textiles]"*.
In chapter 4, the 'Aesthetic part' is presented, which elaborate on the aesthetic qualities of textiles in regards to hospital interiors, and a case study on health care related architecture is presented in paper D: *"Interior textiles and the concept of atmosphere – A case study on the architectural potential of textiles in Danish hospital interiors"*. The theoretical background studies are then contextually explored in experimental studies. These experiments present a preference study conducted at Hospital Vendsyssel, Hjørring, Denmark, presented in paper E: *"Interior design and healing architecture: A mixed-method study on the patients' preferences for interior textiles and textile-based furniture for future hospitals"*, and a study on the patients' experiences of a refurbished

Fig. 1.5 Project structure

Project parts	Sections	Papers
Part 1: "Introduction"	Introduction	
	Research approach	
	Research questions	
	Research contribution	
	Structure of the thesis	
Part 2: "Research methodology"	Introduction	
	Pragmatism	
	Research-through-design	
	System of inquiry	
	Research methods of the individuel studies	
	Technical studies	
	Asthetic studies	
Part 3: "Technical part"	Introduction	
	Background studies	Paper A
	Hypotheses	
	Experimental studies	Paper B and Report C
	Summary	
Part 4: "Aesthetic part"	Introduction	
	Background studies	Paper D
	Hypotheses	
	Experimental studies	Paper E and Paper F
	Summary	
Part 5: "Conclusions and reflections"	Conclusions	
	Reflections	

hospital dayroom at Odense University Hospital, Denmark, presented in paper F: *"Home-like hospital environments - How furniture and materials in a refurbished hospital dayroom influence the patient experience"*.
The final chapter 5 'Conclusions and reflections', combines the technical and aesthetic project parts, and presents an integrated model of design qualities of functional textiles in hospital interiors. Based on the project findings, new approaches for additional research studies are then proposed.

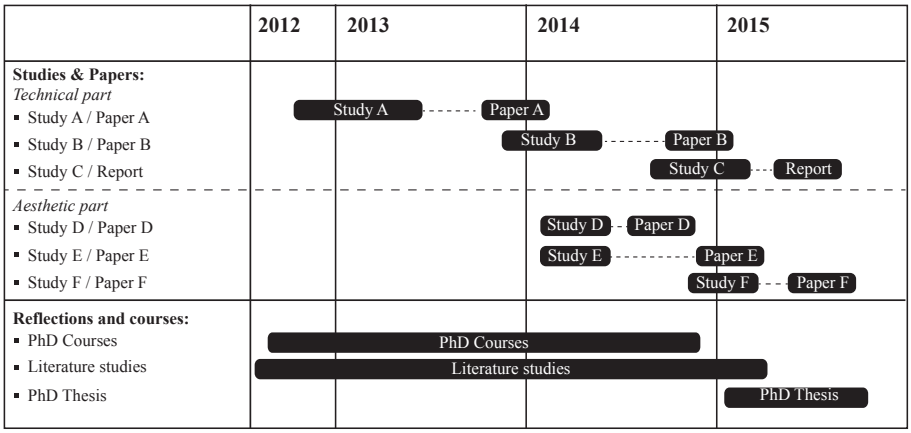
RESEARCH METHODOLOGY

RESEARCH METHODOLOGY

As introduced, the PhD project is based on a cross-disciplinary research approach, seeking to explore if functional textiles technically can be used in Danish hospital interiors, and explore how the textiles aesthetically may contribute to an improved patient experience in hospital environments.
With this technical and aesthetic foundation, the project is amongst the first studies that explore the potentials of using functional textiles in hospitals interiors. To facilitate this research within an undiscovered field, the overall methodology will depart from an exploratory approach framed in the field of design research. This chapter will thus present the philosophical position and methodology of the thesis that can guide the exploratory nature of the project with combined and integrated methodological approaches. The cross-disciplinary approach is considered essential to unfold the field of functional textiles in hospital interiors, and the different technical and aesthetic studies will naturally relate to different methodologies. The project therefore comprises six different studies, which individually has been conducted to cover parts of the project field (fig. 2.1).

The methodology chapter begins by introducing pragmatism (Peirce 1931-58) as the overall paradigmatic framing that can support both the technical and aesthetic aspects of studying functional textiles in hospital interiors. Departing from this philosophical position, the methodology 'research-through-design' (Brandt, Binder 2007, Koskinen et al. 2011, Bang et al. 2012) will be presented as an approach to work with complex problems through exploratory and experimental studies. Having established the overall paradigmatic and methodological foundation, the chapter will present an operational 'system of inquiry' (Groat, Wang 2002) that can combine the different 'schools of thoughts', 'strategies' and 'tactics', that is included in this PhD thesis.

Fig. 2.1 Overview of project activities, studies and related papers



PRAGMATISM

The cross-disciplinary nature and the combination of different project phases and methods calls for an overall paradigmatic framing that can facilitate this unified methodological stance and embrace the combination of different types of studies. Pragmatism is from this perspective seen as a philosophical position, which enables the fusion of different approaches, and proposes adoption of different types of knowledge and inquiries relating to the overall project field (Denscombe 2008).
Emerging from an encounter with the traditional dualism in western academics, the paradigm embrace the significant impact of logical empiricism, as well as it stresses that knowledge is anchored in real collective problems, and must be considered social by nature (Delanty, Strydom 2003).
Development of knowledge is therefore taking place in different ways and in a variety of contexts. In this project this ontological and epistemological multiplicity corresponds with the cross-disciplinary merging of both technical and aesthetic aspects. Knowledge is thus not only developed through a scientist's synthetic conclusions, but also more broadly through the creative overcoming of problems (Delanty, Strydom 2003).
Concerned with the interdisciplinarity of the project, the pragmatic paradigm furthermore supports the exploratory approach, where the abductive process and inference provides the foundation for knowledge production regarding the yet unknown phenomenon. Experiences from previous situations and exploratory background studies are thus used to inform actions and experiments (Lübcke 2010, Delanty, Strydom 2003).

Relating knowledge production to an abductive reasoning, as in Peirce's (1931-58) pragmatism, the process of inference logically joins deductive and inductive principles. While deduction investigate if a theoretical hypothesis can be confirmed, induction uses empirical data to define a plausible theory. By combining these approaches, the abductive process uses previous experiences and knowledge to define new theories or hypotheses, which subsequently are qualified through deductive studies and experiments (Peirce 1931-58).
The experimental and abductive approach is used in the project, where the new phenomenon of functional textiles in hospital interiors is explored. Through a range of studies, new knowledge structures are formed, which are tested and evaluated through contextual experiments. Abduction is thus an appropriate approach to address concerns, problems and possible solutions, which not necessarily are evident in the immediate context, but through hypothesis making and studies, can be explored and unfolded (Strübing 2007, Peirce 1931-58, Kolko 2010, Walton 2014).

The pragmatic position facilitates the cross-disciplinary and dynamic development of the exploratory project, where different methods are essential to unfold the problem field. At the same time, this combination of different methods enables communication with the different actors and promotes the cooperation between researchers and involved stakeholders (Johnson, Onwuegbuzie 2004). The technical inquiries and studies

may relate to the field of hospital hygiene, applying the epistemological foundation and methods traditionally used within this field, while the aesthetic aspects relate to architectural theory recognized and acknowledged by the architects designing and constructing the hospitals (research methods are further described in fig. 2.3 and on pp. 37).

The project is thus situated on the continuum between positivism and constructivism, seeking an applicable and practical approach to the philosophical dualism. In that way, focus is targeting a strong basic empiricism, concerned with what works in terms of methods from different traditional philosophical stances (Johnson, Onwuegbuzie 2004). To frame a cross-disciplinary design research project, pragmatism may thus relate to the methodological pluralism, where different and some times even conflicting theories and perspectives can be integrated to explore the new phenomenon studied.

RESEARCH-THROUGH-DESIGN

As mentioned briefly in the introduction, the project departs from the research methodology research-through-design, seeking to combine different academic fields in order to investigate the specific areas of the problem field with an exploratory approach. The methodology traces back to the publications by Bruce Archer (1995) and Christopher Frayling (1993), who discussed and proposed directions for systematising design research within the traditions of academic research. Archer relates 'research through practice' to action research, defined as a *"systematic investigation through practical action calculated to devise or test new information, ideas, forms or procedures and to produce communicable knowledge."* (Archer 1995, p. 6).

According to Archer, research about practice can be conducted within various research traditions depending on the objectives. Art and design criticism relates to the Humanities; studies on design in regards to people and society falls under the Social Sciences; studies on materials and the processes in which they are used in relates to the appropriate Science disciplines; while studies of the methodologies of art and design are included in the discipline of design research. Common to all studies about practice, however, is that if they are to be acknowledged as research, they must employ the methods and principles of the academic field they belong to (Archer 1995), which also facilitates the dissemination of new knowledge to the stakeholders. This is particularly essential concerned with this cross-disciplinary project that relates to the field of hospital design as well as the field of functional textiles. To conduct academic research, and to provide valuable findings, the methods that are applied to the research studies should therefore relate to the traditions within these fields.

As Archer's statement on research about practice clarifies, design research reveals a methodology, where different methods are combined and used independently within an overall research design that focuses on the actual problem, as also emphasised in the pragmatic paradigm. Research-through-design thereby establish a methodological

framework, where the design practice is combined with research, and where the experimental approach to problem solving are acknowledged in the research project (Koskinen et al. 2011).

In the introduction to a publication on design research epistemologies, professor Ole B. Jensen (2010) relate to the same general definition of design research as Koskinen et al. (2011), while emphasizing that design research projects often seek to provide new solutions to complex practical problems. Concordant with Archer (1995), Jensen argues that most projects rarely relates to one single epistemological framing, but crosses the boarders between the Humanities, the Social Sciences and the Natural Sciences, and combines epistemologies like phenomenology, hermeneutics and even positivism (Jensen 2010). As it will be further unfolded in the following sections describing the individual studies, this combination is essential to unfold the technical concerns of using textiles in hospitals and the aesthetic exploration of the textiles' design qualities. The epistemological and methodological hybrid of design research relates closely to the paradigm of pragmatism, combining technical, social and aesthetic approaches to holistically explore or solve complex design problems. Reflecting the real-life design projects, the research-through-design project enables an integration of different methods, theories and even epistemologies in a united research design (ibid).

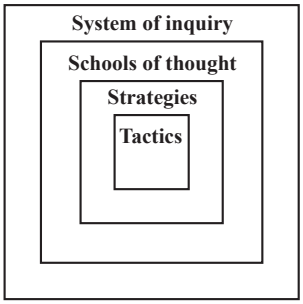
As indicated by the term 'research-through-design', or 'constructive design research' in Koskinen's terminology, the design object itself (being a product, system, space, media, etc.) is often introduced as a central element in the research project. By conducting experiments, the hypothesis is tested and evaluated, and the outcome is informing the research agenda. In this exploratory PhD project, these experiments are introduced as part of the abductive reasoning, where initial theoretical or empirical studies have provided the foundation for testing new hypotheses through the experimental approach. The experiments are therefore combined with supporting studies, including literature studies, interview studies and case studies as an approach to provide initial background knowledge for the experimental hypotheses testing (see the following chapters presenting the methods of the individual studies, pp. 37).

In Koskinen et al.'s (2011) otherwise comprehensive description of the research-through-design methodology, focus on the ontological or paradigmatic origin of design research often appears absent, and the academic grounding of the research approach is not specifically defined or discussed. To establish the scientific framing of this PhD project more specifically, I will introduce the 'system of inquiry', as defined by the architectural theoretician Linda Groat and David Wang (2002).

SYSTEM OF INQUIRY

As Jensen (2010) also implies, Groat and Wang (2002) argues that the design researcher often refrain from defining an overall paradigmatic stance, although it potentially could have strengthened the research, if the researcher had considered not only the methods, but also the underlying assumptions of the research contribution. Not only does this help to consolidate the research design, and avoid methodological blind spots, but it will also strengthen the communication of the results if the knowledge production relates to the traditions of the relevant actors and target groups. In order to establish a solid research design, Groat and Wang introduce a framework of 4 concentric frames. The overall paradigm, or 'system of inquiry', as it is called in Groat and Wang's (2002) terminology, is framing the entire project or study. This grounding stance is framing the 'schools of thought' in terms of underlying epistemologies, which frames the 'strategies'. The strategy is defined as the different methods used to conduct the research study, and these strategies frame the choice of 'tactics', defined as the specific techniques used (Groat, Wang 2002).

Fig. 2.2 System of inquiry in the project



Based on Groat and Wang (2002).

Although the system of inquiry model is not predetermining the choices, there should be a coherence and continuity between the frames (Groat, Wang 2002).
The integration of technical and aesthetic aspects of the project thus needs an intersubjective or pragmatic system of inquiry to link the cross-field of studies that relates to different schools of thought, strategies and tactics. The challenge with the pragmatic approach, however, is to balance the multiple epistemologies and still secure a philosophical and methodological coherence of the different project phases. A transparent overview and consistency of the research project's methodology is therefore needed, and in that regard, I will present the different methods and theories in terms of 'schools of thought', 'strategies', and 'tactics' in an overall 'system of inquiry' (fig. 2.3).

Fig. 2.3 Overview of the project phases and the overall 'System of inquiry'

System of inquiry
Pragmatism

Project phase	'Schools of thought'	'Strategies'	'Tactics'
Technical part:			
Study A *Explores the field of functional textiles and the possibilities of application in the hospital context.*	Hermeneutic (*Evaluation and interpretation of actor meetings and interviews)*	User studies: *Exploratory interviews* Literature review	Actor meetings with representatives from the hospital environment and the textile industry (see diagram fig. 2.6). Review of literature within the field of functional textiles, and hospital hygiene and cleaning.
Study B *In-situ study that explores the possibility of cleaning functional, hydrophobic textiles in a hospital environment.*	Positivism *(Test of the cleaning potential of functional textiles)*	Experiment: *Cleaning test* Literature review	Microbiological sampling on textile surfaces in a hospital environment. Review of literature on hospital textiles and hygiene concerns.
Study C *Laboratory study that examine the cleaning potential, the possibility of disinfecting functional textiles, and the durability of the hydrophobic coatings.*	Positivism *(Test of the cleaning and disinfection potential of functional textiles)*	Experiment: *Cleaning test; disinfection test; and durability test*	Visual evaluation on the functional textiles cleanliness after standard hospital cleaning; Microbiological sampling after disinfection tests; and test of abrasion resistance of the hydrophobic textile coating.
Aesthetic part:			
Study D *Defines a theoretical framework for exploring and unfolding the design qualities of textiles for hospital interiors.*	Hermeneutic *(Case study analysis – hospital atmospheres)*	Case study Literature review	Analysis of different health care environments, where textiles may promote an accommodating interior atmosphere. Review of literature in the field of architectural atmosphere.
Study E *Explores the patients' preferences for furniture and upholstery for hospital interiors.*	Hermeneutic *(Mixed-method study on patients preferences)*	User study: *Patient interviews*	Semi-structured interview with 43 patients' about their preferences for hospital furniture and materials.
Study F *Explores how patients' experience textiles and the home-like atmosphere of a refurbished hospital dayroom.*	Hermeneutic and phenomenology *(Design experiment – re-furbished hospital dayroom)*	Experiment: *Design-based user study* *Patient interviews*	Observations and Semi-structured in-depth interviews with patients' and staff about their experience of a re-furbished hospital dayroom.

The structure of the overview is inspired by Jensen (2010), while relating to the terms of 'system of inquiry' as defined by Groat and Wang (2002).

This overview presents the pragmatic 'system of inquiry' that frames the different studies and the integration of various methods throughout the project. The corresponding 'schools of thought', all relate to traditional epistemological fields. A hermeneutic epistemology is directing the studies involving users in interviews and observation studies, seeking to understand the problem field from the users' perspective. The data obtained through these studies is interpreted based on hermeneutical principles, aligning the separate parts of the interview and actions, etc. to the experience of the whole (Kvale 1997, Gadamer 2008, Delanty, Strydom 2003). Interpretation thereby becomes an iterative process, where themes are defined and constructed to gain a more profound understanding of the phenomenon of inquiry. The researcher, whose previous experiences are affecting the interpretation, influences this iterative interpretation process, corresponding with the exploratory and abductive approach within the pragmatic philosophical position. Furthermore, the hermeneutic epistemology facilitates the construction of hypotheses, which is a central part of the projects methodological framing and structure.

In the final experimental study on the aesthetic qualities of interior textiles, the epistemology relates to hermeneutics and combines this with a phenomenological understanding (Merleau-Ponty 2009, Pallasmaa 2005) of the patients' aesthetic experience. In the experiments of the technical part, where microbiological and hygiene studies are conducted, the epistemological position departs from a positivistic framing (Delanty, Strydom 2003). The ability of cleaning and disinfecting textiles is studied empirically through objective and quantitative data related to standardised methods of microbiological sampling and cleaning observation.

The methods of the individual studies that relate to this system of inquiry, will be presented as summaries in the following chapters in regards to the technical and aesthetic studies, respectively.

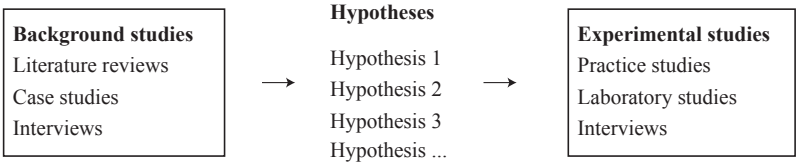
RESEARCH METHODS OF THE INDIVIDUAL STUDIES

As described, the PhD thesis consists of different studies within the technical and aesthetic domain of using functional textiles in hospitals interiors. Before describing the methods of the individual studies, I will elaborate on the abductive reasoning that has guided the process of defining these studies.

THE ABDUCTIVE PROCESS AND ORGANISATION OF STUDIES

The technical and aesthetic parts of the project have been initiated with background studies, where the related project concerns are unfolded and discussed from different empirical and theoretical perspectives. The technical background studies explore the possibilities of applying functional textiles in Danish hospital interiors, relating to textile coating technologies (Study A), and elaborate on the hygiene concerns and requirements of using textiles in hospital interiors. The aesthetic background studies includes an analytical case study (Study D), where the textiles influence on the interior design atmosphere has been theoretically discussed.
With the experience and knowledge gained in the exploratory background studies, hypotheses are constructed and qualified through testing and evaluation in a range of experimental studies, according to the process of abductive reasoning (fig. 2.4). The technical experimental studies include a hospital practice study (Study B) and a laboratory study (Study C), seeking to provide knowledge on whether the functional textiles can be cleaned and disinfected, and thereby are technically applicable for the hospital interior. The aesthetic experimental studies includes two user studies. First, patients at Hospital Vendsyssel, Hjørring have been interviewed about their preferences for hospital furniture and materials (Study E), and then a design experiment has been conducted at Odense University Hospital, where the patients' experience of a refurbished dayroom has been explored (Study F).

Fig. 2.4 The process of abductive reasoning



Based on the process of abductive reasoning as put forward by Peirce (1931-58).
Experience and knowledge gained in background studies are used to construct hypotheses that are qualified through experimental studies.
Hypotheses are presented on page 64 and 95.

Relating to this process of abductive reasoning, the methods of the individual studies will be presented in the following chapters, presenting the background studies first, followed by the experimental studies of the technical and aesthetic project parts, respectively.

TECHNICAL PART - RESEARCH METHODS

BACKGROUND STUDIES

The background studies composes a literature study (fig. 2.5) and several exploratory interviews (figure 2.6). The overall purpose of the background studies have been to provide an overview of the different functional textiles that may promote the hygiene level of hospitals, and to explore which types of materials that may be applied in the Danish health care sector. The findings of this part of the background study are also presented in paper A: *"Design Innovations and Implementation Challenges – A Case of Smart Textiles in Future Hospital Interiors"*. As this project is one of the first studies to address focus on the use of functional textiles in Danish hospital interiors, the approach in the background study has been exploratory in order to unfold the cross-disciplinary field from a broad perspective.

The literature study departed with a state-of-the-art review of functional textiles, combined with the reading of national standards, regulations and guidelines that compose the cleaning practice at Danish hospitals. The study included an initially systematic search in scientific databases, but as the relevance of the results here were limited (fig. 2.5), the search was altered to direct review papers that was combined with cross-reference searches in order to elaborate on particular issues in the cross-disciplinary field. Later in the project, literature was also found in searches using databases or Google scholar to find particular information or studies on more specific areas of concern (for instance Silicon Dioxide and hydrophobic properties; Bacteria resistance of Silver ions, etc.).

To contextualise the literature, interviews and meetings with a range of different actors from both the hospitals and the textile industry were conducted (see fig. 2.6). These meetings with the hospital and textile actors followed an exploratory approach, seeking to gain contextual knowledge on how to understand and relate the field of functional textiles to the hospital practices. The semi-structured interviews were conducted as conversations with key-stakeholders and were based on a range of themes and questions defined prior to the meetings (Kvale 1997). After these meetings, a summary and note was written and archived for later use. It was considered to perform these meetings in a more formal setting, with recordings and transcription of the interviews, but in the early phase of the project, the intention of these meetings was to gain unfiltered contextual knowledge from the stakeholders. In the first meetings it were experienced that the stakeholders were more honest and critical towards the contextual challenges,

when the meetings were held at a more informal level without recordings, etc. This way, the initial conversations with stakeholders and key actors often contributed with different and new perspectives on the overall project field that could later be documented through literature or more formal interviews if needed.

Fig. 2.5 Systematic literature review - functional textiles

Phase 1: Overall search on functional textiles for hospital interiors

Databases included:

- Academic Search Premier
- ProQuest
- Science Direct (Elsevier)

Search terms:

”Functional textiles” OR ”Smart textiles” OR ”Coated Textiles”
AND
”Hospital” OR ”Health Care”
AND
”Hydrophobic” OR ”Water Repellent” OR ”*bacterial” OR ”*microbial” OR ”Hygiene”

Search results:

Database	Total hits (journals)	Abstracts	Papers
Academic Search Premier	5	2	-
ProQuest	18	8	2
Science Direct (Elsevier)	254	12	4

Phase 2: Search for review papers on functional textiles

Databases included:

- Science Direct (Elsevier)

Search terms:

”Functional textiles” OR ”Smart textiles” OR ”Coated Textiles”
AND
”Hydrophobic” OR ”Water Repellent” OR ”*bacterial” OR ”*microbial” OR ”Hygiene”

Filter refined:

Keywords: textiles

Database	Total hits (journals)	Abstracts	Papers
Science Direct (Elsevier)	55	16	8

The construction of the literature review is based on the PhD Course: “Research Information Management”, held at Aalborg University, 3rd of October 2012.
Total hits: Number of papers found in the database.
Abstracts: Number of selected abstracts based on review of paper titles.
Papers: Number of relevant papers based on review of selected abstracts.

Fig. 2.6 Overview of the key actors involved in the background study

The hospital organisation

- Hospital Vendsyssel, Hjørring
  The Service department
- Aalborg University Hospital
  The Regional hygiene team
- Statens Serum Institut
  The Central unit of incection control and hygiene
- MTIC
  MedTech innovators in Central Denmark Region
- Danish Technological Institute
  The microbiology department
- Design School Kolding
  The research team involved in an earlier project on hospitals and textiles
- Aalborg University
  The research team involved in an earlier project on hospitals and textiles

The textile industry

- Gabriel A/S, Aalborg
  The design department
- Kvadrat A/S
  The sales agent for 'health' in Denmark
- Danish-Art-Weaving
  The manager
- DFD (National Steam Laundry)
  The managers involved in 'health' related projects
- Nobicon A/S
  Danish distributor of NanoPool SiO2 coatings
- Clariant
  Distributor of antibacterial and hydrophobic additives for textiles
- Sanitized
  Distributor of antibacterial additives for textiles
- DTU
  Research team involved in Nanotechnology risk assesments
- The Danish Environmental Projection Agency
  The environmental technology department

Note: The inverviews and meetings are primarily conducted in the first phase of the project (2012 and 2013).

The actors included in the background study interviews were selected in order to contextualise the knowledge gained through the literature study. The exploratory background study has thus provided different perspectives, insights, research results, actor opinions, and analyses that together have constituted the findings. The results of the background study, presented in the technical part of the project, have then defined the hypotheses that are tested in the technical experimental studies.

EXPERIMENTAL STUDIES

The purpose of the experimental studies has been to explore if the functional textiles can be cleaned and disinfected, and thereby are applicable for the hospital context. In the PhD project, the experiments are characterised as pilot-studies, with the purpose of identifying indications on the technical potentials of applying textiles in hospital interiors. The time frame of the PhD project has not rendered it possible to test and evaluate the textiles' technical performance in long-term studies, and the aim of the experiments have instead been to explore the possibilities of using functional textiles from different perspectives. In order to address the hypotheses defined in the background study, the experiments are specifically exploring: The possibility of cleaning functional textiles in practice at a hospital (Study B); The possibility of removing different types of soil from the functional textile surfaces (Study C1); The possibility of disinfecting the functional textiles (Study C2); The durability of the hydrophobic coatings of the functional textiles (Study C3).
The following sections will provide an overview of the methods in the individual studies. The methods of study B are described more thoroughly in paper B: *"A microbiological evaluation of SiO_2 coated textiles in hospital interiors: The effect of passive coatings on the cleaning potential of interior textiles"*, while the methods of study C1-C3 are explained in more detail in this thesis, as the related report C: *"Tekstiler til fremtidens hospitaler – rengøring og desinfektion af funktionelle tekstiler - [Textiles for future hospitals – cleaning and disinfection of functional textiles]"*, is only available in Danish.

Study B - Practice related cleaning test

The purpose of Study B has been to explore if the functional textiles could be cleaned through traditional daily cleaning in a hospital setting. The study relates to a practice test at Hospital Vendsyssel, Hjørring, where four different kinds of textiles; 1) non-coated polyester; 2) non-coated wool; 3) SiO_2 coated (hydrophobic/water repellent) polyester; and 4) SiO_2 coated (hydrophobic/water repellent) wool; were installed on hospital chair armrests.
Through a 3-week period the quantitative level of bacteria on the textile surfaces were measured by microbiological evaluation, using 'dipslides' (agar plates for evaluation of bacteria presence) to sample the surface for bacteria before and after traditional hospital cleaning. According to the national standard for hospital cleaning (Danish Standard, DS2451-10:2014), the limit value of bacteria shall be below 2,5 CFU/cm^2 (Colony Forming Units, A count of all viable bacteria on a sample). Based on this criterion it was evaluated whether the different textile surfaces failed or passed the microbiological test sampling. The results (presented in the technical section), indicates that it is possible to clean the textiles in daily practice, and based on this observation, a range of laboratory tests are initiated (Study C).

Study C - Laboratory test studies

Study C includes three different laboratory studies, which has been conducted as part of the project *"Tekstiler til fremtidens hospitaler – rengøring og desinfektion af funktionelle tekstiler - [Textiles for future hospitals – cleaning and disinfection of functional textiles]"* hosted by VIA University College, VIA Design and funded by the Innovation Cluster "Innonet – Interior and clothing". In these tests, chief consultant Poul-Erik Jørgensen, VIA Design has contributed with assistance in conducting the tests.
The individual experiments in Study C include a 'Laboratory cleaning test' (Study C1); a 'Laboratory disinfection test' (Study C2), and a 'Laboratory durability test' (Study C3). In the three studies, the textile materials have been the same, as they are based on Trevira CS polyester (Gabriel Step), which then have been coated with three different products providing a hydrophobic/water repellent surface (table 2.7).

Table 2.7 Materials used in the experimental studies C1 - C3

Description	Product	Producer	Technology
Polyester, Trevira CS	Gabriel, Step	Gabriel	Untreated
Hydrophobic Coating 1	NP	NanoPool	Silicon dioxide
Hydrophobic Coating 2	zeroF	CHT/BEZEMA	Paraffin
Hydrophobic Coating 3	Repellan	PulcraChemicals	Paraffin

Study C1 - Laboratory cleaning test

The purpose of study C1 has been to explore if the hydrophobic textiles can be cleaned with the standard hospital cleaning method (wiping with a damp or wet cloth containing a cleaning agent (Danish Standard, DS2451-10:2014) (see also the chapter 'Requirements for functional textiles', p. 60). In the test, the textiles were stained with three types of representative soil, including protein-based soil (swine blood) (Fijan et al. 2007, Lund 2015); water-based soil (coffee) (Lund 2015); and fatty soil (swine fat mixed with carbon as colour indication) (Fijan et al. 2007).
1 ml of the different soils were applied to the textile surfaces, and after 24 hours of drying, the textiles were attempted cleaned using the standard hospital cleaning method. The evaluation of hospital cleanliness is in daily practice based on visual inspection, where the hospital interiors should appear clean (Danish Standard, DS2451-10:2014). In order to evaluate the cleaning potential of the hydrophobic textiles, the cleanliness were thus evaluated using a 5-step grey scale, where the textiles received grades from 1- 5 (1: clean – 5: not clean), for the different types of soil, respectively. By using the standard cleaning methods, the results show, that the textiles can be cleaned and pass the visual inspection for the blood and coffee soils, but not for the fatty soil (see results in the technical part, p. 69).

Study C2 - Laboratory disinfection test

The purpose of study C2 has been to explore the possibilities of disinfecting the coated textiles. The previous two studies has shown that the textiles are possible to clean to an adequate level both in the daily practice at the hospital, and for the liquid-based soils in the laboratory. For use in hospital interiors, it should however also be possible to disinfect the material in case of bacteria outbreaks or when soiled with human biological material (see also the chapter 'Requirements for functional textiles', p. 60). Today the furniture are disinfected by wiping chlorine or ethanol on the plastic upholstery surface, while the traditional textiles needs to be removed and send to laundry. New disinfection methods, however exists which potentially could be used to disinfect textiles without traditional laundering (see also the chapter 'Disinfection', p. 62).

In Study C2, the SonoSteam technology (steam and ultrasound disinfection, see also p. 62 for further description) was used for disinfecting the four different textiles. The test was performed in cooperation with FORCE Technology's SonoSteam specialist Hanieh Sadat Musavian.
1 ml of TVC (total viable count) bacteria solution was inoculated on the textiles before they were treated with SonoSteam for 1 sec. After the treatment the bacteria level was determined through microbiological analysis. Here the textile samples were placed individually in stomacher bags together with 90 ml buffered peptone water and were pulsified in 30 seconds. This transfers the remaining bacteria from the textiles to the peptone water. The peptone water was then analysed for microbial organisms using 3M petrifilm.

The test was performed with four different sets of textiles. Two sets received the SonoSteam treatment, while two sets were not disinfected, but were used as control groups to define the effect of the disinfection.
As the results show (see technical part, p. 71) the SonoSteam treatment is highly efficient in killing the microorganisms on the textile surfaces.

Study C3 - Laboratory durability test

While the two first studies of Study C have provided knowledge on the cleaning and disinfection potential of the coated textiles, the purpose of the final Study C3 has been to examine the durability of the hydrophobic textile coatings. If used for hygiene improving effects in hospital interiors it is essential that the coatings are durable to withstand the use by many different patients and visitors.
To test this durability two standard test methods for textiles were used.
First the hydrophobic effect was evaluated using water/alcohol solution resistance test (ISO 23232:2009), where drops of 8 different solutions with various water/ethanol combinations (table 2.8) were placed on the textile surface. These different solutions each have different surface tensions, and by exploring when the drops of liquid will

spread on the textile, it is possible to determine the surface energy of the textile surface (ISO 23232:2009).

Table 2.8 Standard test liquids - The water/alcohol resistance test

Repellency grade number	**Composition** Water/alcohol solution	**Surface tension** (dyn/cm at 25°C)
0	Fails the 98:2 solution (grade 1)	-
1	98:2 (water/isopropyl alcohol)	59,0
2	95:5 (water/isopropyl alcohol)	50,0
3	90:10 (water/isopropyl alcohol)	42,0
4	80:20 (water/isopropyl alcohol)	33,0
5	70:30 (water/isopropyl alcohol)	27,5
6	60:40 (water/isopropyl alcohol)	25,4
7	50:50 (water/isopropyl alcohol)	24,5
8	40:60 (water/isopropyl alcohol)	24,0

Based on: (ISO 23232:2009)

To test the abrasion resistance, the Martindale method (ISO 12947-2) was used, which determine the possible wear on the textile coating. By rubbing the textile against a woollen standard textile, the number of rotations were counted, and for different intervals (0-60.000 Martindale) the hydrophobic effect of the coated textiles were defined. The Danish Technological Institute defines the abrasion resistance for hospital upholstery as minimum 25.000 Martindale (Danish Technological Institute 2013), which the coated textiles therefore ideally should fulfil. In comparison the textile itself is defined with an abrasion resistance of 100.000 Martindale (Gabriel A/S, Step). The results of the durability study show that the surfaces can withstand 25.000 Martindale, and that the hydrophobic properties are maintained to some degree for 60.000 Martindale as well (see the technical part, p. 72).

AESTHETIC PART - RESEARCH METHODS

In the technical part of the project, the background studies were based on empirical studies, while the hypotheses were tested in positivistic studies. However, as it is more difficult - if not impossible - to conduct positivistic studies on the patients' aesthetic experience of textiles, the aesthetic part have been approached differently. Nevertheless, the process of abductive reasoning has still governed the aesthetic studies, where background studies have defined a range of hypotheses for testing in experimental studies. Through the background studies a theoretical perspective to explore and accentuate the aesthetic qualities of textiles has been established, while the experimental studies have sought to contextualise the theoretical perspective to the patients' concerns through exploratory empirical studies.
In the thesis, the background studies will be presented before the experimental studies, but as indicated in the project overview (fig. 2.1, p. 30), the theoretical studies have not necessarily been concluded before the experimental studies have been initiated. The process has been more iterative than the structure in the thesis reflects, and the results from the first experimental study on patients' preferences have naturally affected the approach in the theoretical studies as well. In the theoretical chapter on 'tactility' (pp. 92) I also describe how the patients handle the textiles in the experimental study on preferences, although this study is presented later in the thesis (pp. 97).

BACKGROUND STUDIES

The background studies consist of theoretical chapters on 'aesthetics', 'atmosphere', 'familiarity' and 'tactility', as well as a case study on the use of textiles in health care related architecture. The purpose of the theoretical chapters has been to outline different understandings of the aesthetic perception, and to accentuate how textiles may affect the patients' experience of hospital interiors. As the project's focus is directed on interior textiles, I have concentrated on theories that relates to the sensuous stimulation and affection of architecture and interiors. The theoretical framing has not been related to a single philosophical direction, but has combined what I have found relevant in terms of phenomenological approaches and theories relating to environmental psychology. As I elaborate on in the chapter 'human-environment interaction' (p. 82), I am aware of this epistemological challenge of combining phenomenology and environmental psychology, but I have found it appropriate to take this stance in order to explore how the textiles may affect the experience of hospital interior design.

The aesthetic background studies are mainly based on a literature study, which included an initial systematic search on hospital architecture and the use of textiles (see fig 2.9). Focus in the early phase of the project was directed on hospital architecture, as this context was considered to constitute a characteristic setting, but later in the project, literature was broaden to include other health care related settings in terms of nursing homes, care centers, counseling centers, etc.

Fig. 2.9 Systematic literature review - hospital architecture

Phase 1: Overall search on hospital architecture and textiles

Databases included:

- Academic Search Premier
- ProQuest
- Science Direct (Elsevier)
- PubMed
- DAAI: Design and applied arts index

Search terms:

”Hospital architecture” OR ”Healing architecture” OR ”Hospital interior design”
AND
Textiles

Search results:

Database	Total hits (journals)	Abstracts	Papers
Academic Search Premier	8	2	1
ProQuest	4	-	-
Science Direct (Elsevier)	1	-	-
PubMed	-	-	-
DAAI	-	-	-

Phase 2: Search on hospital architecture

Databases included:

- Science Direct (Elsevier)

Databases included:

- Academic Search Premier
- ProQuest
- Science Direct (Elsevier)
- PubMed
- DAAI: Design and applied arts index

Search terms:

”Hospital architecture” OR ”Healing architecture” OR ”Hospital interior design”

Search results:

Database	Total hits (journals)	Abstracts	Papers
Academic Search Premier	37	10	4
ProQuest	170	16	4
Science Direct (Elsevier)	137	3	-
PubMed	-	-	-
DAAI	2	-	-

The construction of the literature review is based on the PhD Course: “Research Information Management”, held at Aalborg University, 3rd of October 2012.
Total hits: Number of papers found in the database.
Abstracts: Number of selected abstracts based on review of paper titles.
Papers: Number of relevant papers based on review of selected abstracts.

As illustrated in the diagram, the database search on hospital architecture and textiles provided very limited results, and in the second phase of the literature study, the search was broaden to focus on hospital architecture in general. Still the results were limited, and the search was therefore combined with cross-reference searches in review papers. Ulrich et al.'s review *"A review of the research literature on evidence-based healthcare design"* (Ulrich et al. 2008), Frandsen et al.'s review *"Helende arkitektur"* (Frandsen et al. 2009), and especially Birgit Cold's comprehensive work on *"Aesthetics, Well-being and health"* (Cold 2001, Cold, Kolstad & Larssæther 1998), have been key references in this cross-reference search for literature on hospital interior design.
The concept of atmosphere, which is introduced in regards to the definition of architectural aesthetics, is explored on the basis of the philosopher Gernot Böhme (Böhme 1993, Böhme 1998, Böhme 2013a, Böhme 2013b), the architectural theorist Juhani Pallasmaa (Pallasmaa 2013, Pallasmaa 2005, Pallasmaa 2001) and the practicing architect Peter Zumthor (Zumthor 2006), which in recent years have published different contributions to the discussion of architectural atmospheres. The theoretical study on tactility and familiarity as particularly relevant subjects in regards to the use of textiles in hospital interiors was based on searches in databases and Google Scholar seeking for review papers that could provide an overview and promote cross-reference searches.

Besides the literature studies, the background studies also include a case study on the use of interior textiles in a cancer counselling centre and a hospice. The methodology for this study is presented in paper D *"Interior Textiles and the Concept of Atmospheres - A Case Study on the Architectural Potential of Textiles in Danish Hospital Interiors",* and is shortly summarised in the next section.

Study D - Case study

The purpose of the case study was to explore how textiles were used in health care related architecture, and analyse how the textiles contributed to the experienced atmosphere. The outcome of the case study thus aimed to accentuate and articulate the aesthetic qualities of textiles in regards to future hospital design.

The cases chosen for the study included a recently build cancer counselling centre in Herning, Denmark, and a hospice in Ringkøbing, Denmark.
The analysis was based on a visit to the locations, where the atmosphere was experienced, and where the use of interior textiles were registered and documented with photographs and notes. Based on the personal experience, photographs and notes, an architectural analysis of the cases was performed relating the experience to the concept of atmosphere as put forward by Böhme (1993, 1998, 2013a, 2013b), Pallasmaa (2013, 2005, 2001) and Zumthor (2006). The case study concludes with the presentation of a conceptual framework, for accentuating and articulating the aesthetic qualities of using textiles in hospital interiors (presented in the aesthetic part).

EXPERIMENTAL STUDIES

The purpose of the aesthetic experimental studies has been to relate the background studies' theoretical perspective to the patients' experiences through empirical inquiries. The experimental studies will thus have an exploratory character, seeking to provide an insight in how the patients perceive and experience textiles in the hospital environment. The studies are presented in the two papers *"Interior design and healing architecture: A mixed-method study on the patients' preferences for interior textiles and textile-based furniture for future hospitals"* (Paper E), and *"Home-like hospital environments – How furniture and materials in a refurbished hospital dayroom influence the patient experience"* (Paper F). The next two chapters will present a summary of the methodological approaches to these studies, and for a more detailed description of the methods, I will refer to the papers.

Study E - Preference study

The purpose of the study has been to explore if the patients' general preference for more home-like interiors (Danish Patients 2009, Horsburgh 1995, Lawson, Phiri & Wells-Thorpe 2003), could be linked to a preference for textiles in hospital interiors.

To address the patients' preferences, the study was conducted as a mixed-method study and included interviews with 43 patients at the outpatient lung department at Hospital Vendsyssel, Hjørring.
Although the main interest was the patients' concerns and preferences for textile upholstery, the study also included questions on the patients' preferences for different types of armchairs as textile-based furniture. Cardboards with pictures of the armchairs (see fig 2.10) were presented to the patients, and they were asked about their preference for a future hospital dayroom, as well as their reasons for preferring the selected chair. As illustrated in the figure, the chairs were selected to define a scale ranging from a typological hospital chair (Chair 1), to a very home-like chair (Chair 5). Chair 5 was included to illustrate and indicate that the patients were allowed to consider new ideas for future hospital interiors.
After the patients had selected and motivated their preference, they were presented with 5 different types of upholstery, which also ranged from a typical hospital upholstery (Material A) to more home-like upholstery types (Material C-E).
The same approach was followed, and the patients selected and motivated their preferences for a future upholstery material. Finally, the patients were asked about their general experience of the hospital interior.

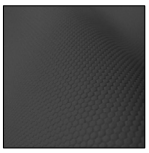
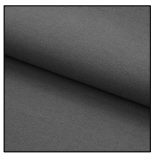
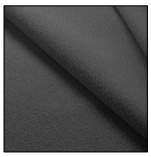
Fig. 2.10 Furniture and materials presented for the patients

Furniture

				
Chair 1	**Chair 2**	**Chair 3**	**Chair 4**	**Chair 5**
The Bern Chair Wooden frame of lacquered beech, with plastic upholstery. A typical design for traditional Danish hospital interiors.	**Wegner GE-290** Wooden frame of oak, upholstered with a soft woollen fabric. The shape and the wooden frame associate with hospital furniture.	**Wegner AP-27** A full upholstered seat and back, with wooden legs and armrests. The chair balances the home-like and the institutional design tradition.	**Polo** Full upholstered and soft armchair. Associate with traditional chairs for a living room. Not typical for the hospital environment.	**Spectra** A lay back armchair with a very soft seating. Included to indicate for the patients that new thoughts and ideas on future hospital design is allowed.

Note: In this table, the chairs range from a typical hospital chair as chair 1, and a very textile-based chair as chair 5. When presented for the patients, changing the numbers of the chairs randomised this range.

Materials

				
Material A	**Material B**	**Material C**	**Material D**	**Material E**
Wafer by Maharam (Kvadrat). The surface is 100 % polyurethane. A dull surface with a machine made structure of smaller dots. Represents the easy-to-clean plastic upholsteries used at hospitals today.	**Plot (Kvadrat).** 100 % Trevira CS, Polyester. The textile appears to be very light, and represents a material that with a smooth surface would seem to be easy to maintain.	**Hallingdal 65 (Kvadrat).** 100 % wool. A semi-coarse texture, representing traditional woollen upholstery that has been used for Danish classical furniture.	**Outback (Kvadrat).** 80 % wool. Boucle yarn in both directions gives an unstructured surface, with a distinctive texture and a soft sense of touch.	**Perla 2.2 (Kvadrat).** 100 % wool. Made with double threads, and has a very coarse surface and texture. The structure gives a clear visual oversized pattern.

Note: In this table, the textiles range from typical hospital upholstery as Material A, and a coarse woollen upholstery as Material E. When presented for the patients, changing the numbers of the material samples randomised this range.

As presented in paper E: "Interior design and healing architecture: A mixed-method study on the patients' preferences for interior textiles and textile-based furniture for future hospitals".

The interviews were recorded, transcribed and analysed through the data software nVivo and Tableau, where different themes were defined and the quantitative dataset was analysed.

As I will present in the paper and later in the thesis, a large group of the patients' surprisingly preferred the traditional hospital armchair and material. This however, could be linked to the patients' expectations toward the hospital environment, and as the paper concludes preference studies might not be the right approach to explore the patients' experiences. Instead, the paper suggests that full-scale mock-up studies may be a better approach to conduct empirical studies on the patients' experiences of the interior design.

Study F - Experience-based study

The last experimental study relates to the patients' experiences and builds on the findings from the previous experiment (Study E) that suggest that the method of design-based mock-up studies is more appropriate to explore the patients' interior design experiences. The purpose of the study has thus been to gain knowledge on how a more home-like hospital atmosphere affect the patients' experience.

The study was conducted in cooperation with architects and designers at the Health Innovation Centre in Southern Denmark, who directed a project on hospital interiors in waiting areas and dayrooms at Odense University Hospital (Kjærsig, Linaa 2015). Together with the project managers it was decided to conduct a design experiment at the Nephrology department, and through a three-week period the dayroom at the ward was refurbished to imbue a more home-like atmosphere. The qualitative study then sought to explore if this home-like interior would improve the patients' experience, and how interior textiles might influence this experience. The design changes are illustrated in the pictures (ill. 2.11 og 2.12), and are explained in detail in paper F.

As it is evident from the design changes, the intention was not to propose new innovative interiors for hospitals, but rather to promote the experience of the interior by including basic, home-like references and materials.

To collect data on the patients' experiences, a triangulation of three qualitative methods was applied, including patient observations, patient interviews and staff interviews. The observations were performed for 2 consecutive days, where the patients' behaviour and activities were passively observed, and the observation thus provided an immediate impression of the patients' use of the room. After the observation, patient interviews were conducted with four different patients. The interviews were semi-structured, and focused particular on the patients' experience of the refurbished dayroom. Finally, the charge nurse was interviewed to qualify the patient statements, as her prolonged observation and interaction with the hospitalised patients could be used to generalise the patient observations and interviews. Data from the observation and interviews were

subsequently transcribed and analysed for themes using the software nVivo. As with the previous studies, the methods are described in further detail in the related paper (Paper F).

As the results indicate (presented in the aesthetic chapters), the patients have a very positive experience of the refurbished dayroom, and emphasise how the textiles contribute to this experience.

Ill. 2.11 Existing dayroom at the Nephrology department at Odense University Hospital.

Ill. 2.12 Refurbished dayroom at the Nephrology department at Odense University Hospital

TECHNICAL PART

INTRODUCTION

In this section of the PhD, I will address focus on the technical aspects of using functional textiles in the interior of Danish hospitals.
Today most hospitals are designed and furnished with materials that are easy to clean and maintain, but as addressed in the introduction of the thesis, the use of these plastic materials also imbue a certain institutional and clinical atmosphere. Instead of using plastic upholstery in the hospital interior, the field of functional textiles has provided an interesting alternative that could relate to the rational requirements for efficient cleaning, while at the same time respond to the emotional requests for accommodating hospital interiors. I will later present the field of functional textiles, and thus for this introduction simply establish that despite an increase of new textile materials and products, they are still not implemented in a Danish hospital context.
One of the main reasons for this lack of implementation may be related to a confined awareness on the alternatives of functional textiles, which I address in the paper *"Design Innovations and Implementation Challenges – A Case of Smart Textiles in Future Hospital Interiors"*. So far practice related research on functional textiles for hospital interiors is limited (as illustrated in fig. 2.5, 'Systematic literature review', in the methodology chapter, p. 39), and the effect and qualities of using these new materials thus needs to be investigated before the textiles can be considered for use in the hospital environment.

The section on the textiles technical qualities will thus explore the possibilities of using functional textiles in the interior of Danish hospitals, focusing on the technical demands of hospital hygiene. To address this concern, the section will more specifically explore the following operational sub-questions:

- Which types of functional textiles with hygiene improving properties are available, and which will be most suited for the Danish hospital context?
- Which criteria should the functional textiles fulfil in terms of hospital hygiene, relating to the Danish requirements of cleaning and disinfection?
- Can the functional textiles be cleaned and disinfected in an adequate manner?

The first sub-question seeks to map the different technologies and types of functional textiles and regard the possible use of these materials in a Danish hospital context, considering the values, opinions and concerns of the relevant decision-makers in the national health care organisation. The findings of this study are presented in the chapter 'The field of functional textiles', which partly builds upon paper A *"Design Innovations and Implementation Challenges – A Case of Smart Textiles in Future Hospital Interiors"*.

The second sub-question is concerned with the national standards and guidelines for hospital cleaning and disinfection. If the functional textiles should be used in future Danish hospitals, they should comply with the standards of hospital hygiene. The overview of these criteria for use is presented in the chapter 'Requirements for functional textiles', leading to the formulation of four hypotheses for testing in the experimental studies.

The third sub-question is addressed in two experimental studies, where a practice-related study on the cleaning potential of functional textiles is conducted at Hospital Vendsyssel, and a laboratory study on the cleaning and disinfection potential is conducted in the textile laboratory at VIA University College, VIA Design. While the empirical background studies will have an exploratory nature, the experimental studies in this technical part will have a more normative character, referring to the research process of abductive reasoning (see the methodology chapter, p. 37).

The technical experiments are in the thesis summarised with the main findings, and are also presented in Paper B: *"A microbiological evaluation of SiO_2 coated textiles in hospital interiors: The effect of passive coatings on the cleaning potential of interior textiles"*, and the report "*Tekstiler til fremtidens hospitaler – rengøring og desinfektion af funktionelle tekstiler - [Textiles for future hospitals – cleaning and disinfection of functional textiles]*", published by VIA University College (as the report is only available in Danish, the results from these experiments are presented in greater detail in the thesis).

Through the rest of the technical chapters, I will present the findings from the background studies, establish the hypotheses and present the results of the experimental studies.

BACKGROUND STUDIES
THE FIELD OF FUNCTIONAL TEXTILES

The first chapter in the technical background studies will address the first sub-question: *Which types of functional textiles with hygiene improving properties are available, and which will be most suited for the Danish hospital context?*

Functional textiles are materials that have been technically designed with added functionalities, which may include, flame retardant properties, anti-static properties, improved strength, heat or cold resistant properties, etc. (Kiekens et al. 2014, Cherenack, van Pieterson 2012). In this project the functional textiles in scope are designed to improve the level of hygiene, with either antibacterial properties (Gao, Cranston 2008, Vilcnik et al. 2009) or water and dirt repellent properties (Türk, Ehrmann & Mahltig 2014, Yao, Song & Jiang 2011, Mahltig, Haufe & Böttcher 2005).

Functional textiles are generally related to the field of *smart textiles*, which are defined as materials with the ability to sense and react to environmental conditions or stimuli (Tao 2001). The exact definition of smart textiles, have earlier been discussed extensively within the field, seeking to establish *how* smart a material or textile should be in order to gain the definition of a smart material (Black 2007). From that concern, Hooper et al. (2003) argues in a report on smart materials, that the term 'smart' naturally suggest a certain degree of consciousness, which does not exist in a non-biological system: *"There is arguably no such thing as a 'smart material' per-se – only materials that exhibit interesting intrinsic characteristics which can be exploited within systems or structures that, in turn, can exhibit 'smart' behaviour."* (Hooper et al. 2003).

There is today a fundamental agreement that the field can be divided in two main categories, where the *smart textiles* can sense and react to environmental stimuli, while the *functional textiles* are passive textile materials with added functionalities (Cherenack, van Pieterson 2012).

In regards to hospital interiors, the field of smart or functional textiles has provided different ideas and technologies that could promote the level of hygiene. In 2006, researchers from Cornell University presented their intentions for the development of a 'smart napkin' that based on textile sensors could detect bacteria presence on for instance food objects (Ulrich 2006). The intention was later developed into a prototype that could trace the appearance of *e-coli* bacteria (Barad 2006), but since then the prototype has not been further developed or been ready for use in practice. There are apparently different challenges of progressing the prototype, but the idea of detecting bacteria in real-time through textile sensors have been established. If likewise technologies at some point could be commercialised, it could be a significant potential for hospital organisations if the bacteria outbreaks could be traced through textile sensors in the hospital interior environment. It will most likely be another decade or two before these future scenarios are ready, tested and implemented in hospital interiors, but the

potentials of smart textiles in hospitals are remarkably.
However, in this project, which focuses on hospitals under current construction, the smart textile scenario is considered too futuristic for approaching application, and focus is instead directed on the field of functional textiles. These technologies and materials are already available and commercialised in other industries, and with less advanced properties these materials could still promote the hygiene level of hospitals, which will be unfolded through the following chapters.

FUNCTIONAL TEXTILES WITH HYGIENE IMPROVING PROPERTIES

The field of functional textiles with hygiene improving properties can coarsely be divided in two groups of active *antibacterial* textiles or passive *hydrophobic* textiles (Höfer 2006). While the antibacterial textiles actively kill bacteria in contact with the surface, the hydrophobic textiles are water and dirt repellent and inhibit bacteria growth, thereby providing a more cleaning-friendly surface. Common to these functional textiles, the visual appearance and tactile experience of the materials are similar to traditional textiles, and it is only in contact with liquids or bacteria that the added functionality is evident.

Research on the application of functional textiles in hospitals is, as addressed in the methodological chapter, very limited. Only 6 relevant papers were identified in a systematic literature search within the field of functional textiles for the hospital interior (fig. 2.5, 'Systematic literature review', p. 39). From the reading of review literature (Gao, Cranston 2008, Türk, Ehrmann & Mahltig 2014, Kiekens et al. 2014, Höfer 2006, Hooper et al. 2003) it is, however, evident that other studies exist, but the field seems divided in two general directions. First of all is the development to a large extent driven by the industry, and seeking rapid commercial success, the new products are rarely tested and evaluated in scientific studies (e.g. NanoPool only includes newspaper articles in their 'list of publications' on their web page (NanoPool 2015), and no previous scientific publications are found in database searches). On the other hand, research institutes develop new types of coatings or additives, and in this process of innovative developments, the technical solutions often seems to be years from potential commercialisation.
The functional textiles with hygiene improving properties have, however, been available for the market for more than a decade, and the antibacterial textiles are already introduced to the international health care market, e.g.: Ege Carpets' Texture Care (carpets for the health care sector); Oniro Niroxx (upholstery for the health care sector); COBI Rehab (Comfort foam mattress for the health care sector). The hydrophobic textiles has not yet received as much attention in the health care market, but is well-known in the context of outdoor clothing, where products like Teflon have been used to provide a water-repellent coating for jackets, pants, shoes, etc.

In paper A *"Design Innovations and Implementation Challenges – A Case of Smart*

Textiles in Future Hospital Interiors", I have presented an overview of the two groups of antibacterial and hydrophobic textiles, and have elaborated on which type of materials that are best suited for the Danish hospital context.
So far it has primarily been the antibacterial textiles, which have been attempted implemented in the international, and national, hospital context, but as the paper address, there is a strong national scepticism towards the use of antibacterial materials, as they are in risk of causing increased bacteria resistance. Statens Serum Institut [The National Serum Institute], who is the main national counsellor of hospital hygiene and infection control, thus caution against the use of these materials in their "National Guidelines for Hospital Design" (Statens Serum Institut 2013), stating that:

"The content of specific antimicrobial additives for interior objects, equipment and textiles are not currently recommended, as there generally is lacking knowledge on the long-term effects, environmental risks, and the risk of developing bacteria resistance." (Statens Serum Institut 2013) [Translated by author].

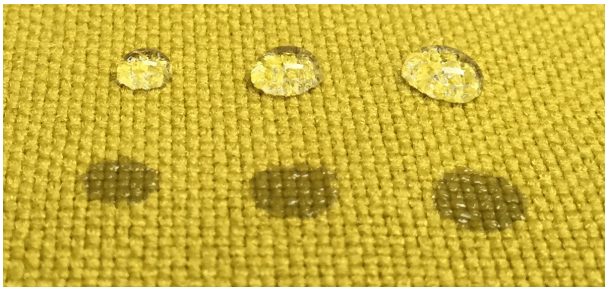
Despite this clear position and statement from Statens Serum Institut, some Danish producers have still sought to sell in antibacterial products to the Danish hospital context. Textile companies have antibacterial products in their product catalogue (e.g. Danish Art Weaving – the product Oniro Niroxx), and in a recent interview, a Danish floor company states that they expect their antibacterial flooring to be the standard in future Danish hospitals (Magasinet Gulv 2013). Concerned with the general disregard of the antibacterial materials, it is paradoxical that the Danish suppliers presents these materials for the Danish hospital service departments, instead of developing new solutions that are consistent with the values of the Danish hospital organisation.
As discussed and evaluated in paper A, the Danish hospitals thus provide a very poor implementation climate for antibacterial textiles. There is nevertheless a strong potential in progressing the development of the hydrophobic textiles instead, which can link to the values of the hospital organisation. Through the rest of this technical part of the project, I will thus relate to these hydrophobic textiles and explore if these materials can comply with the hygiene standards of Danish hospitals.

HYDROPHOBIC TEXTILES

The hydrophobic textiles are based on passive technologies that provide a water and dirt repellent textile surface. For hospital furniture, these functional textiles could provide an easy-to-clean surface, which to some extent is comparable to the plastic upholstery used today.

When a water drop gets in contact with a normal textile surface, the two materials will be attracted to each other, and the water will spread and wet the textile. Technically, this is due to the internal cohesive interactions of the water that are lower than the adhesive interaction between the drop and the textile surface (Schindler, Hauser 2004). By

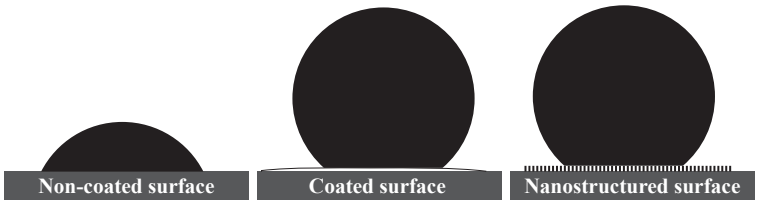
manipulating with the textile surface, either by chemical or physical structural changes (fig. 3.2), the surface energy of the textile can be lowered. If the textile's surface energy is lower than the internal surface tension of the water drop, the drop will not be attracted to the textile surface, and will remain intact instead of spreading out (see ill. 3.1).



Ill. 3.1 Illustration of drops of liquid that are repelled by the textile surface and remains as drops, and drops that are attracted to the surface and spread out.

The textiles can be altered with hydrophobic properties by coating the textile through a sol-gel or chemical process (Mahltig, Böttcher 2003, Türk, Ehrmann & Mahltig 2014), or by creating a fine web of small nano-scaled solid particles on the material surface (see fig. 3.2.) (Gulrajani 2013). On this nanostructured surface, the liquid drop will be in contact with the air molecules formed between the solid elements of the nanostructured surface, and as the contact between the drop and the surface is reduced, the intermolecular forces that normally draw the materials together are lowered (Pan et al. 2012).

Fig. 3.2 Different approaches to alter a hydrophobic textile surface



Based on Gulrajani (2013).

The water repellent effect of the hydrophobic textiles depends on many different factors, including fibre type, textile construction, material density, and the water repellent

product. Earlier, fluorocarbon-based products have been used for their hydrophobic properties, but the contents of the hormone-disruptive and environmental toxic PFOA or PFOS synthetics have exterminated most of these products today (Jensen, Poulsen & Bossi 2008). Instead, new technologies have been developed, and 'flouro-free products' based on for instance silicon dioxide (SiO_2), paraffin, silicones or polyurethane are already introduced to the market (Mahltig, Böttcher 2003, Tomšič et al. 2008, Schindler, Hauser 2004).

Besides the water- and dirt repellent surface that may improve the cleaning ability of the textiles, the low surface energy of the textile also constitutes a poor environment for bacterial growth as the bacteria attachment to the surface is confined and the possibility of producing biofilm is reduced (Mucha et al. 2002, Höfer 2006, Daoud, Xin & Tao 2004, Yao, Song & Jiang 2011, Tomšič et al. 2008).

In the first chapters of the technical section in the thesis, I have established that functional textiles with passive hydrophobic properties are most applicable for use in the Danish hospital context. The advantages of the passive hydrophobic textiles are fundamentally that they do not pose a risk of increased bacteria resistance, but instead provide a cleaning-friendly textile surface that could be compared to the plastic materials that are used in the Danish hospitals today. The functional textiles, however, still possess the same aesthetic, tactile and recognisable qualities as traditional textiles, and the technical qualities of the hydrophobic textiles are from a theoretical perspective promising. However, as the materials have not yet been used in the hospital environment, the technical qualities of the material should necessarily be evaluated and tested, before the materials' appropriateness for the hospital environment can be fully affirmed. In the later following experimental studies, I will initiate some of these evaluating tests on the cleaning ability, the disinfection ability and the coating durability.

REQUIREMENTS FOR FUNCTIONAL TEXTILES

As addressed in the introduction, the functional textiles should comply with the regulations and standards of hospital cleaning procedures. In this chapter, I will thus relate to the second sub-question: *Which criteria should the functional textiles fulfil in terms of hospital hygiene, relating to the Danish requirements of cleaning and disinfection?*

In Denmark the requirements are defined in different standards and guidelines relating to hospital cleaning and hospital disinfection, respectively.
Methods for hospital cleaning are described and defined by the standardisation organisation in Denmark "Dansk Standard" [Danish Standard], while the recommended methods for disinfection are defined in the “Nationale Infektionshygiejniske Retningslinjer for desinfektion i sundhedssektoren” [National guidelines for disinfection at hospitals], published by Statens Serum Institut [The National Serum Institute]. These standards and guidelines will be the basis for this chapter, where I will summarise

the current practice of hospital cleaning and disinfection, which the functional textiles essentially should fulfil.

In regards to hospital hygiene, the standards and guidelines distinguish between *cleaning* and *disinfection*. The purpose of cleaning is to remove dust, dirt and micro-organism in order to prevent bacteria growth, while disinfection is the process where micro-organisms are extensively killed so the disinfected area or object can be used with no risk of infections.

Hospital cleaning

Hospital cleaning is today performed in Danish hospitals according to the Danish Standard: DS 2451 – part 10: "Infection control in the health care sector - Requirements for cleaning" (Danish Standard, DS2451-10:2014).
According to the standard, hospital cleaning shall be conducted sufficiently often for rooms, fixture and furniture to appear clean, and the evaluation of room cleanliness are thus based on a visual inspection, where 10 critical risk points are examined. This visual inspection to control the daily cleaning process is used in most Danish hospitals, although the standard also proposes a microbiological evaluation, which according to the standard could be used for some specific areas of the hospital (Danish Standard, DS2451-10:2014). In the experimental study on the cleaning potential of functional textiles, this microbiological evaluation is used, and the method is therefore described more thoroughly in paper B, and the methodology section.

The actual cleaning of hospital furniture and equipment follow a specific cleaning method described in the standard. Upholstery and furniture are in the standard defined as patient rests, and shall be cleaned by 'cleaning method 3', defined as *"damp wiping with a clean cloth and clean water containing a cleaning agent, with mechanical rubbing of the surface"* (Danish Standard, DS2451-10:2014, p. 15). In cases of high degree of soiling, 'cleaning method 4', is used instead, defined as: *"wet cleaning with a clean cloth and clean water containing a cleaning agent, with mechanical rubbing of the surface and wiping afterwards with a clean cloth"* (ibid).

In most cases, these cleaning methods are considered sufficient to maintain an adequate level of hygiene in the hospital environment. However, in cases of bacteria outbreaks, or when the interior surfaces are soiled with human biological materials (blood, secretions or excretions) the standard cleaning method should be followed by full disinfection.

Disinfection

The national guideline for disinfection in hospitals is published by Statens Serum Institut [The National Serum Institute]. From this guideline, heating is described as the preferred method for disinfection, but in cases when this method is not possible, a chemical disinfectant can be used instead.
Concerned with the disinfection of hospital furniture, traditional textiles shall be washed at 80°C in 10 minutes (Danish Standard, DS2451-8:2013), which causes the bacteria to decompose. However, as the process of traditional washing in most hospitals is considered too time consuming, the use of plastic upholstery allow a more efficient disinfection process by wiping the surface with a chemical disinfectant of ethanol or chlorine. As the textile surface is micro-structured and potentially perforated, surface wiping has not been adopted as an appropriate method for disinfection of traditional textiles (Statens Serum Institut 2014).
There are however new disinfection methods available that potentially could be used to disinfect interior textiles. Room disinfection is one of these methods that have gained ground at Danish hospitals in recent years (Statens Serum Institut 2014). After a thorough cleaning of the room, a disinfection process is initiated, where a machine diffuse a fog of disinfection agent (hydrogen peroxide, ozone, or chlorine dioxide) (Statens Serum Institut 2014). The method has a great potential, but there are still issues regarding the disinfection of equipment and especially furniture, due to the presence of organic material that can inhibit the disinfection effect (Statens Serum Institut 2014).
An alternative method, which could be used for textiles, is disinfection with SonoSteam (this method is also used in the technical experiments, Study C2). The technology is invented by FORCE Technology, and was originally intended for the purpose of disinfection in the food industry, but the method has now been further developed to include other areas of disinfection as well. Recently, the technology has thus been adopted for disinfection of hospital mattresses at Hvidovre Hospital (FORCE Technology 2014).

Ill. 3.3 Test equipment for SonoSteam treatments at FORCE Technology.

SonoSteam is a disinfection process that utilise a combination of steam and ultrasound to achieve an effective heat-based disinfection in only a few seconds.
In traditional steam cleaning, the zone of air closest to the surface of the object acts as a protective layer, which inhibits vapour and heat exchange across the surface. The ultrasound sets the air in this laminar zone in oscillation, causing the steam to be forced towards the micro-structural surface of the material very rapidly. Because of the small size of micro-organisms they will quickly be affected by the heat, and will decompose (FORCE Technology 2014) .

Fig. 3.4 Process of steam-based disinfection without and with ultrasound (FORCE Technology 2014) .

As it is evident from the standards and guidelines for hospital cleaning and disinfection, all interior surfaces, should be kept clean in daily practice by wiping a damp or wet cloth with a cleaning agent. In case of soiling by human biological material or in case of bacteria outbreaks, the surfaces should further be disinfected by heating or by use of chemical disinfectants.
If the functional textiles should be used in future hospital interiors, it is thus relevant to test and evaluate if these hydrophobic materials can comply with these standards and guidelines, and to evaluate if new methods of disinfection, as for instance the SonoSteam treatment can be used on the hydrophobic coatings.

BACKGROUND STUDIES – SUMMARY AND HYPOTHESES

In the previous chapters I have presented an overview of the field of functional textiles that potentially could contribute to the hygiene level of Danish hospital interiors. As I have addressed, and discussed in paper A, the technology of functional textiles should relate to the Danish hospital organisation, and from that perspective I have focused on the passive hydrophobic textiles as a potential material for Danish hospitals.
However, as emphasised in the introduction of this technical section, the functional textiles should comply with the standards and guidelines for hospital cleaning and disinfection. Having unfolded these criteria for cleaning and disinfection in Danish hospitals, I will define a range of hypotheses for testing in the experimental studies.

The hypotheses are concerned with the possibilities of cleaning and disinfecting the hydrophobic textiles, as it is considered essential to document these technical qualities before the materials can be implemented in the hospital context. The hypotheses are stated below, with a short paragraph motivating the formulation of the hypotheses:

Hypothesis 1:

> *The functional textiles can be cleaned in daily practice so that the bacteria level are below the critical limit value of 2,5 CFU/cm^2.*

Motivation:
Concerned with the lack of practice-related research on the application of functional textiles in hospital interiors, the first hypothesis seeks to explore if the hydrophobic textiles can be cleaned in a daily hospital practice. To evaluate the cleaning potential, the microbiological evaluation method, as defined in the Danish Standard (DS2451-10:2014) is used. From this standard, the bacteria level on all interior surfaces for patient rest, should be below a critical limit value of 2,5 CFU/cm^2 (Colony Forming Units; A count of all viable bacteria on a surface sample).

Hypothesis 2:

> *The functional textiles can resist different types of soil by cleaning with the standard methods as defined in Danish Standard (2014).*

Motivation:
While the first experimental study test the cleaning ability in a hospital environment, this hypothesis focus particularly on the cleaning ability against different types of traditionally resistant soil.

Hypothesis 3:

> *The functional textiles can be disinfected properly by the use of the SonoSteam disinfection method.*

Motivation:
Concerned with the requirements of adequate disinfection, the third hypothesis will explore if the functional textiles can be disinfected thoroughly by the use of the SonoSteam method.

Hypothesis 4:

> *The hydrophobic coating is durable enough to withstand the abrasion that is required for a hospital environment.*

Motivation:
One of the main challenges with hydrophobic textiles is often the durability of the coating. To evaluate if the coatings can withstand the use in a hospital context, the final hypothesis relates to this issue and test the hydrophobic properties depending on different levels of abrasion.

EXPERIMENTAL STUDIES

The experimental studies will relate to the hypotheses through four individual experiments, including a practice related study conducted at Hospital Vendsyssel, Hjørring (Study B), and a laboratory study conducted in the textile laboratory at VIA University College, VIA Design in Herning (Study C1-C3).
In the thesis I will present the experimental studies with a short introduction stating the purpose of the particular experiment, before highlighting the findings and results. Study B is also presented in paper B: *"A microbiological evaluation of SiO_2 coated textiles in hospital interiors: The effect of passive coatings on the cleaning potential of interior textiles"*, and Study C in report C: "Tekstiler til fremtidens hospitaler – rengøring og desinfektion af funktionelle tekstiler " [Textiles for future hospitals – cleaning and disinfection of functional textiles], published by VIA University College, VIA Design in association with an innovation project funded by the Danish Innovation Cluster "Innonet – Interior and Clothing". As this report is only available in Danish, the results of these experiments are presented in greater detail in the thesis.

STUDY B – PRACTICE RELATED CLEANING TEST

Purpose:
Study B relates to the first hypothesis, exploring if the functional textiles can be cleaned in daily practice. The purpose was specifically to evaluate if a hydrophobic textile could provide a textile surface with an improved cleaning ability and hygiene potential for hospital interiors. The practice related cleaning test was arranged at Hospital Vendsyssel, Hjørring. Having installed different types of textiles on chair armrests in the waiting room, the bacteria level on the different textile materials and the regular plastic armrest was evaluated through a three-week period. The bacteria level was measured with microbiological dipslides before and after a standard cleaning process, wiping the armrest with a damp cloth (cleaning method 3) (see p. 61 for description). To evaluate whether the cleaned surfaces are adequately cleaned, the bacteria level was related to the standard for hospital cleaning (Danish Standard, DS2451-10:2014), stating that the total amount of viable bacteria in microbiological evaluation should be below 2,5 CFU/cm^2 (Colony Forming Unit).

Results:
Table 3.5 presents the results from the study. The bacteria level is here quantified in 4 categories depending on the contamination levels: Scanty contamination (0-2,5 CFU/cm^2); Light contamination (2,5-5,0 CFU/cm^2); Moderate contamination (5,0-15,0 CFU/cm^2); Heavy contamination (15,0 – CFU/cm^2).

Table 3.5 Results from surface sampling on five different armrest surfaces

Armrest surface	Side	24h		48h		1 week		3 weeks	
		Before cleaning	*After cleaning*	*Before cleaning*	*After cleaning*	*Before cleaning*	*After cleaning*	*Before cleaning*	*After cleaning*
1 Polyester *Traditional*	A	Heavy Cont. *(H)*	Light Cont. *(L)*	Light Cont. *(L)*	Light Cont. *(L)*	Moderate Cont. *(M)*	Scanty Cont. *(S)*	Light Cont. *(L)*	Scanty Cont. *(S)*
	B	Heavy Cont. *(H)*	Light Cont. *(L)*	Moderate Cont. *(M)*	Scanty Cont. *(S)*	Moderate Cont. *(M)*	Light Cont. *(L)*	Light Cont. *(L)*	Scanty Cont. *(S)*
2 Polyester + SiO_2	A	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Moderate Cont. *(M)*	Scanty Cont. *(S)*
	B	Light Cont. *(L)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Moderate Cont. *(M)*	Scanty Cont. *(S)*
3 Wool *Traditional*	A	Heavy Cont. *(H)*	Light Cont. *(L)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Moderate Cont. *(M)*	Light Cont. *(L)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*
	B	Heavy Cont. *(H)*	Light Cont. *(L)*	Light Cont. *(L)*	Scanty Cont. *(S)*	Moderate Cont. *(M)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*
4 Wool + SiO_2	A	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Light Cont. *(L)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Heavy Cont. *(H)*	Scanty Cont. *(S)*
	B	Light Cont. *(L)*	Scanty Cont. *(S)*	Light Cont. *(L)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*	Heavy Cont. *(H)*	Scanty Cont. *(S)*
5 Plastic Reference	A	Light Cont. *(L)*	Light Cont. *(L)*	Moderate Cont. *(M)*	Light Cont. *(L)*	Light Cont. *(L)*	Light Cont. *(L)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*
	B	Light Cont. *(L)*	Light Cont. *(L)*	Light Cont. *(L)*	Light Cont. *(L)*	Moderate Cont. *(M)*	Light Cont. *(L)*	Scanty Cont. *(S)*	Scanty Cont. *(S)*

Note: Contamination levels: (S): <2,5 CFU/cm2; (L): 2,5-5,0 CFU/cm2; (M): 5,0 – 15,00 CFU/cm2; (H): > 15 CFU/cm2. Side A and B refer to the dipslides two independent sides (both used on the same textile surface).

As presented in paper B. The green font illustrate that the surface would pass the microbiological evaluation according to the Danish Standard (DS2451-10:2014).

As the results indicates, the armrest surfaces performed differently on the cleaning procedure, and the bacteria level was well above the critical limit value of 2,5 CFU/cm^2 (scanty contamination) for most surfaces before cleaning. In table 3.6 the results are summarised, so the percentages of surface samplings that had a bacteria level below 2,5 CFU/cm^2 are illustrated. Here it is evident that it was only the SiO_2 coated textiles that were possible to clean to a level below the critical limit value.

Table 3.6 The percentage of surface samplings that would pass the evaluation

Armrest surface	*Before cleaning*	*After cleaning*
1 Polyester *Traditional*	0 %	50 %
2 Polyester + SiO_2	62,5 %	100 %
3 Wool *Traditional*	37,5 %	62,5 %
4 Wool + SiO_2	37,5 %	100 %
5 Plastic Reference	25 %	25%

As presented in paper B. The percentages of surfaces that reach a bacteria level below the critical limit value of 2,5 CFU/cm2.

Summary:
The first experimental study indicates that it is possible to clean the functional, hydrophobic textiles in the hospital context, using the cleaning methods that are already used. The results also confirm that it is difficult to clean the traditional textiles with standard cleaning methods, but also the plastic material, included as a reference for a hard surface material, appeared to be difficult to clean. Only 25 % of the after-cleaning measures were adequately cleaned according to the standard. However, as paper B also emphasise the results from this study needs to be related to additional long-term studies that evaluate the bacteria levels through a longer period of time, and laboratory studies that further explore the cleaning potential and the possibilities of disinfection.

STUDY C – LABORATORY TEST STUDIES

Study C includes three different individual studies, which have been conducted as part of the project "Textiles in future hospitals" hosted by VIA University College, VIA Design. The individual studies consist of a "Laboratory cleaning test" (Study C1); a "Laboratory disinfection test" (Study C2), and a "Laboratory durability test" (Study C3), and as mentioned in the methodology chapter, the materials for these three studies are the same: 1) A non-coated polyester; 2) A NanoPool coated polyester; 3) A zeroF coated polyester; 4) A Repellan coated polyester. (See also table 2.7 in the research methodology chapter, p. 42).

STUDY C1 - LABORATORY CLEANING TEST

Purpose:
The study relates to the second hypothesis, seeking to explore if different types of soil can be removed from the functional textiles by standard cleaning methods as defined in Danish Standard (DS2451-10:2014). To test this, the textiles were stained with different types of soil, including protein-based soil (swine blood) (Fijan et al. 2007, Lund 2015); water-based soil (coffee) (Lund 2015); and fatty soil (swine fat mixed with carbon powder as colour indication) (Fijan et al. 2007). As described in the methodology section (p. 42), the soils were placed on the textiles, and allowed to dry for 24 hours before cleaning. According to the Danish Standard (DS2451-10:2014), the textiles were cleaned with a damp cloth (cleaning method 3) or wet cloth (cleaning method 4) (see also p. 61 for further definition). The results present the degree of cleanliness relating to a 5-step grey scale, giving grades from 1- 5 (1: not clean – 5: completely clean).

Results:
The results from the cleaning test are presented in table 3.7 below.

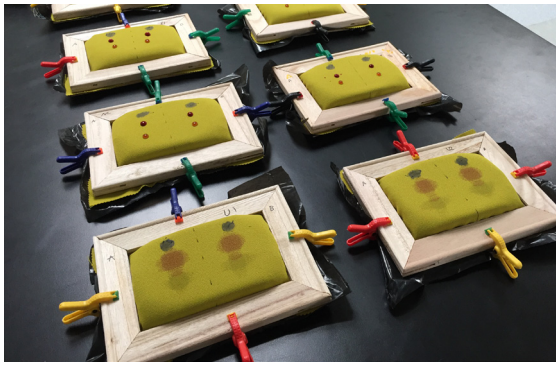
Table 3.7 Results after cleaning according to 'cleaning method 3'

Soil	Non-coated	NanoPool	zeroF	Repellan
Swine fat	1	1	1	1
Swine blood	1	4	5	4
Coffee	3	4	5	4/5

Note: Grades refer to a 5-step grey scale. 1: Not-clean; 5: Completely clean.

'Cleaning method 3' is defined in the Danish Standard (DS2451-10:2014).

The textiles were in the first step cleaned by using cleaning method 3, and as the results indicate the swine blood and coffee stains were almost removed completely from the coated textile surfaces. On the non-coated textile, the stains were spread out making a large stain that was not possible to clean (see ill. 3.8). In comparison, the soil was situated on top of the coated textiles, and could more easily be removed.



Ill. 3.8. Stains on the non-coated textile (foreground), and the coated surfaces (background).

As the NanoPool and Repellan coatings still had small signs of stains after the cleaning method 3, these stains were attempted removed by cleaning method 4 (table 3.9) When the stains were soaked with water, it was possible to clean the NanoPool coated textile completely, while the Repellan coating still had smaller discolours.

Table 3.9 Results after cleaning according to 'cleaning method 4'

Soil	Non-coated	NanoPool	zeroF	Repellan
Swine fat	1	1	1	1
Swine blood	1	5	5	4/5
Coffee	3	5	5	4/5

Note: Grades refer to a 5-step grey scale. 1: Not-clean; 5: Completely clean.

'Cleaning method 4' is defined in the Danish Standard (DS2451-10:2014).

Although the liquid-based stains were possible to clean, the soil of fat and carbon could not be removed from any of the textiles surfaces. The fat appeared to be attached to the textile surface, and the cleaning agent used was not capable of dissolving the fat particles. For this purpose another approach or a fat-dissolving agent is considered needed, but this was not included in this current study.

Summary:
The results from the cleaning test indicates that the coated textiles can be cleaned by the standard cleaning method and provide a visually acceptable result, when stained with the water-based or protein-based soils. The fat-based soil, however, was not possible to remove with the standard cleaning method. Based on these results it would be essential to conduct further studies on different types of soils, and to discover alternative ways of removing the fat-based stains.

STUDY C2 - LABORATORY DISINFECTION TEST

Purpose:
While the fist two experimental studies have addressed the possibility of cleaning functional textiles, study C2 relates to the third hypothesis, seeking to explore if the textiles can be properly disinfected.
In hospitals today, wiping the surface with chlorine or ethanol can disinfect the plastic upholstery, but concerned with the micro-structured and coarse textile surface, this disinfection method is not used for textiles (Statens Serum Institut 2014). As described in the background study on hospital disinfection, the SonoSteam technology, developed by FORCE Technology, could however be an alternative method for disinfecting textiles. To evaluate if the SonoSteam Technology can disinfect textiles, an experiment was conducted in cooperation with FORCE Technology (see also the research methodology chapter, p. 43).

Results:
The results of the SonoSteam disinfection test are presented in the table 3.10 below. In total four sets of textiles were inoculated with a bacteria culture. Two of the sets were then disinfected with the SonoSteam treatment, while the two remaining sets were used as control groups to define the disinfection effect and bacteria reduction. In the table below the results from the two SonoSteam treated sets, and the two control sets are presented as average values.

Table 3.10 Results after disinfection with the SonoSteam treatment

		CFU (/ml)	CFU - log (/90 ml)	Reduction (%)	Reduction (log)
Non-coated	*Control*	2.627	5,37	99,99 %	4,39
	SonoSteam	0,5	0,98		
NanoPool	*Control*	364	4,51	99,66 %	3,53
	SonoSteam	0,5	0,98		
zeroF	*Control*	418	4,57	99,99%	2,47
	SonoSteam	1,5	2,10		
Repellan	*Control*	2.827	5,15	99,97 %	4,02
	SonoSteam	1	1,13		

Note: SonoSteam: Treated for 1 second. Control: Non-disinfected textiles.
CFU/ml: The total CFU in 1 ml of pulsified peptone water.
CFU/90ml: The log value of the total amount of CFUs in the entire pierce of textile.

Test conducted in cooperation with FORCE Technology.

As it is evident from the results, the SonoSteam treatment is very efficient in reducing the bacteria level on all the textile surfaces, with reductions close to 100 %. There were found no specific difference between the non-coated and the coated textiles.

Summary:
Based on these results, the SonoSteam treatment is considered a potential method for disinfecting interior textiles in future hospitals. As described in the background studies, the SonoSteam technology is already used to disinfect hospital mattresses, and according to FORCE Technology, it is also possible to develop SonoSteam equipment for disinfecting hospital textiles or even complete furniture. This way, the removal of the textile upholstery could be avoided, turning the disinfection process more efficient compared to traditional laundering. However, if the furniture should be disinfected by the SonoSteam technology, it would call for new logistics for hospital disinfection, as the furniture would have to be transported to the centrally placed SonoSteam equipment. Additional studies and preferable in-situ tests in a real hospital setting, are therefore needed to provide evidence for the potential of SonoSteam disinfection for hospital interior textiles and furniture.

STUDY C3 - LABORATORY DURABILITY TEST

Purpose:
The results of the first experimental studies have clearly indicated that the hydrophobic textiles can be both cleaned and disinfected, and in the last study I will evaluate the durability of the hydrophobic textile coatings. If the textiles should be used in hospital interiors, it is essential that they can withstand the wear and abrasion in this environment. By applying drops of water/alcohol solutions on the different textiles the hydrophobic property of the materials were defined, and performing this test on textiles that have been subject to abrasion, the durability of the coating was explored.

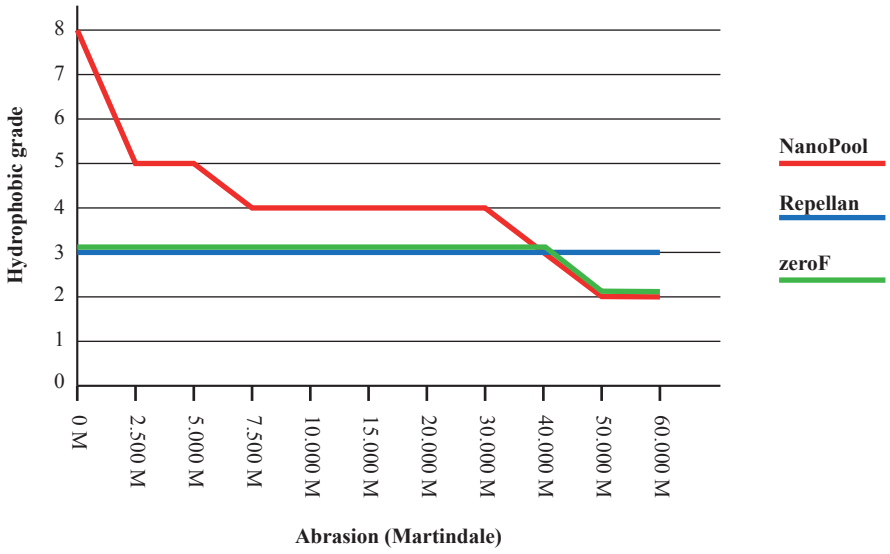
Results:
The results from the durability test, are presented in table 3.11 below. The grades (0-8) in the table respond to the hydrophobic properties of the textiles, where the grade 8 is 'very hydrophobic' and grade 0 is 'non-hydrophobic' (ISO 23232:2009) (see also table 2.8 in the research methodology chapter, p. 44).

Table 3.11 Hydrophobic properties in relation to abrasion

	0 M	2.500 M	5.000 M	7.500 M	10.000 M	15.000 M	20.000 M	30.000 M	40.000 M	50.000 M	60.000 M
Non-coated	0	-	-	-	-	-	-	-	-	-	-
NanoPool	8	5	5	4	4	4	4	4	3	2	2
zeroF	3	3	3	3	3	3	3	3	3	2	2
Repellan	3	3	3	3	3	3	3	3	3	3	3

Note: Grades refer to a 8-step scale. 0: Not hydrophobic; 8: Very hydrophobic. According to: (ISO 23232:2009)

Fig. 3.12 Durability of hydrophobic textiles



As it is evident from table 3.11 and the graph (fig. 3.12), the durability of the hydrophobic coatings are high, and well above the minimum requirement of 25.000 Martindale, which the Danish Technological Institute defines for hospital interiors (Danish Technological Institute 2013).
The silicon-dioxide-based (SiO_2) NanoPool coating performed very good before abrasion was applied (grade 8), but after only 2.500 Martindale, the hydrophobic properties dropped to grade 5, and shortly after at 7.500 Martindale to grade 4, where it is stable until 30.000 Martindale. The paraffin-based coatings, zeroF and Repellan, were very similar in abrasion performance, where the hydrophobic properties of zeroF were stable at grade 3 until 40.000 Martindale, and the Repellan coating performed at grade 3 until 60.000 Martindale.
It remains uncertain why the NanoPool coating was gradually reduced, and the producer of the product has not provided any information regarding this behaviour.
The general durability of the textile coatings are, based on this test, considered substantial high as all the surfaces performs better than the 25.000 Martindale, which the Danish Technological Institute defines as a minimum requirement for hospital interiors (Danish Technological Institute 2013). As the picture below (ill. 3.13) furthermore illustrates, the textile showed visual sign of wear already after 40.000 Martindale, while the hydrophobic properties were still maintained.

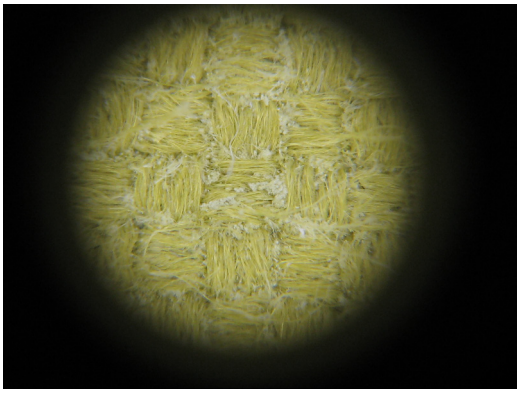


Fig. 3.13 Picture of the textile surface after 40.000 Martindale. The hydrophobic properties are still maintained, but the visual appearance of the textiles shows significant signs of wear.

Summary:
With this final experimental study in the technical section, the results indicate that the hydrophobic coatings can withstand the requirements for use in the hospital environment, when focusing on abrasion resistance. It should, however be tested, whether the cleaning and disinfection processes also have an influence on the coating durability. To provide significant evidence for the textiles durability, a practice related in-situ study would be beneficial to explore the effect of the textiles in real hospital settings.

CONCLUSION - TECHNICAL PART

The purpose of the technical part of the project has been to explore the possibilities of using functional textiles in the interior of Danish hospitals, focusing on the technical demands for hospital hygiene.
The background study has from this perspective provided a broad insight in the field of functional textiles, and has elaborated on the use of these materials in a Danish context. Although the antibacterial textiles had high potentials in promoting the hygiene levels of hospital interiors, the use of these active, bacteria killing materials are not recommended by the national hygiene counsellors. Instead, textiles with hydrophobic and easy-to-clean properties have been proposed as potential interior materials for Danish hospitals. According to the national standards and guidelines on hospital cleaning and disinfection, the hygiene demands for the textiles were defined. Based on the empirical background studies, four main hypotheses relating to hospital hygiene and the durability of the textile coatings were thus defined. As it is evident from the formulation of the hypotheses, the purpose of the experimental studies has been to provide a broad perspective on the cleaning and disinfection potential of the functional textiles. The studies were therefore conducted as pilot-studies, and although the results provided profound indications on the potentials, they should be supported with additional studies to provide more evidence-based documentation. The results of the technical experimental studies have thus provided a solid foundation that may frame future studies within the field of functional textiles for hospital interiors.

The results of the four experimental studies concordantly suggest that the functional textiles with hydrophobic properties can be used in hospital interiors.
The two first studies indicate that the hydrophobic textiles can be cleaned by standard cleaning methods, and the disinfection test showed that the textiles could be successfully disinfected by the SonoSteam treatment, which could be a potential new disinfection process for textile-based hospital furniture. As the size of SonoSteam equipment would require this to be centrally located in the hospital complex, the use of this disinfection method would thus require a new logistic process for transportation of the furniture in need of disinfection. Although this essentially would be more expensive than wiping the plastic-coated furniture with ethanol or chlorine, it is considered conceivable to develop a system that could manage this process. Especially, if the patients' experience of the hospital environment is improved by the more aesthetically pleasing surroundings, which the textiles could provide. In the final experimental study, the textiles durability was evaluated, and in the laboratory study, the hydrophobic property of the textiles was still maintained after 40-60.000 Martindale, which is well above the minimum requirement of 25.000 Martindale, as defined by The Danish Technological Institute (Danish Technological Institute 2013).

Together, the background studies and the four experimental studies have provided new practice related research on the technical possibilities and potentials of using functional textiles in the interior of Danish hospitals, which is considered the first essential step

towards application. However, in the hospital context it is crucial that the materials can preserve the hygiene supporting properties in long-term solutions, and concerning the use of functional textiles, there are still relevant issues to be explored in this regard. Above all the pilot-study results of this thesis should be supported with related studies to provide significant evidence for the hygienic effect of the materials. A prolonged practice related study that monitored the coating durability and the contamination level of the textiles are considered essential, as well as the logistic setup for disinfection should be developed and evaluated.

Nevertheless, these long-term evaluations and developments are not likely to be progressed as long as the demand for interior textiles are not more profound. The motivation for new technical developments is thus considered inferior, and to progress and give reasons for this development, the patient-related benefits of using textiles in hospital interiors, should be unfolded as well. From a design perspective, new focus on the aesthetic qualities of textiles should thus be addressed to increase the hospitals' demand for new functional textiles for hospital interiors. In the second part of the PhD thesis, I will relate to this aesthetic dimension of applying textiles in hospital interiors, and explore how the textiles may improve the patients' experience of the hospital interior.

AESTHETIC PART

INTRODUCTION

Apart from the technical preconditions, which naturally should be fulfilled before textiles can be used in hospital interiors, it is also essential to explore how the textiles can contribute with aesthetic qualities that may affect the patients' experience of the hospital interior.
From a design perspective it is well recognised that the physical environment has an enormous influence on our emotions and general well-being. Proust's (1992) reference to the Madeleine cookie, as a trigger of personal memories, can also be related to experiences of smells, colours, patterns, objects, etc. that through personal memories can generate a certain feeling or mood. As these experiences often are very personal and unique, they will not necessarily have the same affect on others, and it would be difficult – if not impossible – to relate the experience of interiors in hospitals to these personal tastes, styles and memories of the many different hospitalised patients. We do, however also share some collective cultural and biological references to aesthetics (Küller 1991, Pallasmaa 2001), and from a design perspective, the hospital interior is thus likely to provide a more aesthetic experience if they are designed with more focus on these aspects. As these aesthetic dimensions seem to be overlooked in the design of contemporary hospitals, there is a particular need to explore the aesthetic qualities of textiles and to accentuate how these materials may affect the patients' experience.

This project part on the aesthetic qualities of textiles therefore seeks to address:

- What are the aesthetic qualities of textiles that in regards to the current hospital context may improve the patients' experience of the hospital interior?

- How does a hospital interior based on textile objects influence the patients' experience of the interior atmosphere?

As the current amount of research and knowledge on the use of textiles in hospital interiors is very limited (see fig. 2.9, Systematic literature review, p. 46), I will in this project combine theoretical and empirical studies, seeking to contribute with new knowledge on the aesthetic qualities of textiles in regards to hospital interiors. In the same format, as the technical part, this aesthetic part will be based on a range of background studies, seeking to establish a theoretical perspective that can accentuate the aesthetic qualities of textiles. Based on these background studies, some hypotheses will be defined for testing in the following empirical and experimental studies, relating the theoretical framework to the patient perspective. The background studies will be initiated with a short introduction to 'aesthetics', where I will elaborate on 'the essentials of aesthetic environments', and how 'human-environment interactions' can be understood. Subsequently, I will relate to research on 'atmospheres' as an aesthetic concept that relates closely to the experience of interior design. Through a case-study, which also

is presented in paper D *"Interior Textiles and the Concept of Atmospheres"*, I seek to operationalise the concept of atmosphere as a theoretical framework for understanding the aesthetic qualities of interior textiles. 'Familiarity' and 'tactility' are following deduced as two central aesthetic qualities, which textiles can contribute with in hospital interiors. Before the hypotheses for the experimental studies are defined, these two concepts are further unfolded theoretically.
The experimental studies includes a mixed-method study, where patients from Hospital Vendsyssel have been interviewed about their preferences for furniture and furniture materials (presented in Paper E), and a mock-up study at Odense University Hospital, where the patients' experiences of a refurbished dayroom have been analysed (presented in Paper F).

BACKGROUND STUDIES
AESTHETICS

In her very comprehensive work on 'aesthetics, well-being and health' (Cold, Kolstad & Larssæther 1998, Cold 2001), the Danish architect and professor at Norges teknisk-naturvidenskabelige universitet i Trondheim (NTNU), Birgit Cold opens with the concern that aesthetics for some reason often have come last in the planning of public buildings. In our private homes, we are generally concerned with the aesthetic quality, but in public areas, as for instance most hospital environments, the aesthetic influence on our well-being and health is largely underestimated (Cold 2001).
Cold includes an extensive review of existing literature (Cold, Kolstad & Larssæther 1998), as well as new essays within architecture and environmental aesthetics (Cold 2001) to cover different perspectives on the field of aesthetics and health; and although the writings are dated back to the beginning of the last decade, we still witness the same neglect of aesthetic awareness in hospital interiors today. Especially concerning the use of materials, as addressed in the introduction of this PhD thesis. As emphasised by Cold, the aesthetic perception can, however, be a gateway to the emotional and cognitive processes, we may experience when perceiving the physical environment, and aesthetics thereby potentially links with our well-being and health (Cold 2001), as I will elaborate on through these chapters.

'Aesthetics' derives from the Greek 'aisthanesthai', which means 'to perceive', and 'aistheta', meaning 'things perceptible', being a contrast to things that are immaterial. In an approach to define the meaning of the word today, author of the book on 'Environmental aesthetics' professor Douglas J. Porteous (1996) relates to both the Oxford English Dictionary, and the new English Dictionary stating the definition of aesthetic as: ”knowledge derived from the senses” (Oxford English Dictionary) and, ”philosophy or theory of taste; or the perception of the beautiful in nature and art” (new English Dictionary) (cited in Porteous 1996).

These definitions are also addressed by Cold, who at the same time advocates that it is not appropriate to separate these definitions when discussing architecture (Cold, Kolstad & Larssæther 1998). This combined definition of aesthetics will therefore also be used in this project to frame and unfold how specific design qualities of textiles can enhance and promote the patients' experience of the hospital environment.
To address these concerns, a phenomenological perspective will be adopted to explore how the aesthetic experience is affecting our emotions, moods and even existential sphere of life (Pallasmaa 2001), while an environmental psychological perspective will be used to elaborate on how we perceive the world, and which elements influences the aesthetic experience (Küller 1991).

THE ESSENTIALS OF AESTHETIC ENVIRONMENTS

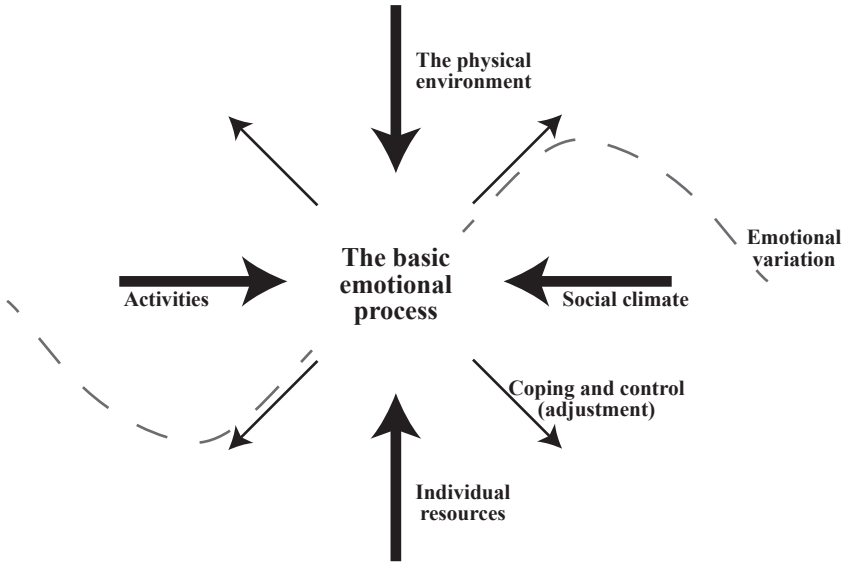
Through this next section, I will elaborate on this unconscious, yet essential, effect the physical environment has on our experience. In his book on ”The Language of Space”, the psychologist and design researcher at The University of Sheffield, Bryan Lawson address how we as humans are inseparable from the spaces we are surrounded by. Not only does the space and the objects determine how we physically can move around, or how hot or cold we feel, the physical environment also influences our mood and unconscious behaviour (Lawson 2001).
Concerned with this connection between the physical space and human experiences, architectural theoretician Juhani Pallasmaa compares the role of the architect with the role of the therapist (Pallasmaa 2001). When we plan and build the physical environment, the architect shape the contents of our minds, as the environment becomes the framework and horizon for our experiences. The therapist deals with the outer conditions of the human being, seeking to adjust the life experiences to these conditions, and according to Pallasmaa, the architect work in the same dimension seeking to improve the experienced space and life horizon. The architecture becomes a mental horizon, where the space is transformed through materiality and geometry to the existential world of experienced value (Pallasmaa 2001).

The task of architecture is therefore not only to provide functionally performing buildings, but extends far beyond the material, physical and measurable conditions into the mental and existential sphere of life. The aesthetic environment becomes the mental mediation between the world and our consciousness, and structures and articulates the existential space (Pallasmaa 2009). This mental sphere of architecture is in its poetic essence grasped through an embodied, aesthetic encounter.
In spaces, where aesthetic dimensions do not support this mental experience, our unconsciousness and bodily reactions can make us feel stressed or even sick (Pallasmaa 2001). When we understand how the physical environment and our minds constantly interact, we understand how important it is that our build environments contain structures and aesthetic qualities that can affect our mind and emotions positively (Pallasmaa 2001).

HUMAN-ENVIRONMENT INTERACTIONS

In order to elaborate on how we are affected by the physical environment, I will introduce the Swedish environmental psychologist Rikard Küller, and his model of human-environment interaction (1991). Environmental psychology is generally concerned with the interactive relationship between the characteristics of the environment and our emotions and behaviour. It is exactly this interaction I seek to address, by introducing Küller's model on human-environment interaction, although Pallasmaa (2001) emphasise that from a phenomenological perspective, it is not possible to separate the mind and the physical world, as environmental psychology attempts to do (Pallasmaa 2001). I am thus aware of the epistemological challenge of combining the perspectives Pallasmaa's phenomenology and Küller's environmental psychology; and although I generally support Pallasmaa's view of space as a multi-sensoric experience, I also acknowledge that models' like the one proposed by Küller, can provide an overview of the complex processes of aesthetic experiences that can support an operational research process. In the project, the combination of these different perspectives is supported methodologically by the pragmatic philosophical approach.

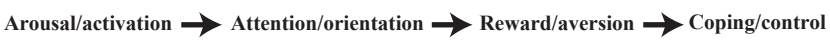
Fig. 4.1 Model of human-environment interaction



Based on the model by Küller (1991).

The model of human-environment interaction, as proposed by Küller (1991), is centred around 'the basic emotional process', which constitute the foundation for human's assessment of the physical environment.

Fig. 4.2 Model of the basic emotional process



Based on Küller (1991).

This emotional process consists of 4 steps (arousal/activation; attention/orientation, reward/aversion (evaluation); and coping/control), implying that every impulse or reticular activation is a precondition for every experience as well as behaviour. Any moderate change in the environment will affect the person's 'attention' and 'orientation', which causes a temporary increase in phasic 'arousal' level, accompanied by feelings of curiosity and exploration desires. If the environmental changes are difficult to classify, exploration and 'evaluation' will occur. If the assessment is good, an approach (physically or mentally) will follow, or if the assessment is bad, a withdrawal will follow. In most cases in everyday life, the assessment will be considered harmless, and we will forget about the 'experience', and habituation will overtime occur. The final step in the emotional process is coping/control, which is the direct actions or psychic processes we adjust to maintain in control of the situation. Coping may thus be observed as a shift in emotional tone (Küller 1991).

According to the model of human-environment interaction, the basic emotional process is partly affected by the physical environment, but in a combination with individual resources, the activities, and social climate the person engage in.
As described through the basic emotional process, the physical environment can activate or arouse the person in different ways, but through the process, we will try to maintain control of the situation (the outgoing arrows in fig. 4.1), by adapting to new strategies or adjusting to the new situation.
Any events that prevent this emotional process from running smoothly will result in adjustments on behalf of the person, and strong or prolonged disturbances may thus lead to stress and general maladjustment. Good evaluations of the physical environment may instead be rewarded as aesthetically pleasing experiences (Küller 1991).

By introducing this model, it has been the intention to present a theory on how we perceive the physical surroundings, and underline how complex this process is. Despite the complexity, it becomes evident that the physical space is an essential condition that frames our experiences and behaviour. Our individual resources, the social climate, the

activities we engage in, and the physical space affects our mood and behaviour through an unconscious process that has essential affect on our experiences in the daily life, and thus also when we are hospitalised. Pallasmaa also refers to this unconscious process, which according to him also defines how we react in different situations and what we like and dislike. A bio-cultural unconsciousness, in the word of Pallasmaa, which can be traced back to our instincts of a reptile, ancient past (Pallasmaa 2001). Pallasmaa continues by criticising how modern architecture and design often produce new and more technological physical environments, without recognizing the archaic instincts that are so ingrown in our biological origin (Pallasmaa 2001). In hospitals especially, this technological alienation is particular pronounced, where a more supporting and accommodating, patient friendly atmosphere, most likely could improve the patients' experience, by being in harmony with their archaic instincts of seeking comfortable, safe and peaceful surroundings.
With these introducing chapters on aesthetics, it has been the purpose to outline how the physical space affect us, and how this effect is also essential when considering or working with hospital interiors.

If the basic emotional process is not running smoothly in the human-environment interaction, this will potentially lead to stress, as proposed by Küller (1991). Related to the hospital context, this observation is essential, as research has established that patients, who are in psychic balance, experience a promoted healing process, while patients affected by stressors will have a reduced immune system, which may influence the healing process negatively (Dirckinck-Holmfeld et al. 2007). When hospitalised, most patients will experience an ultimate stress situation, where the inner stressors relate to the illness or accident, while outer stressors collects all the sense impression the patient meet in the physical environment. In the right accommodating environments, the use of medication to control the level of stress may thus be reduced (Dirckinck-Holmfeld et al. 2007), and as some studies show, the patients healing process may be promoted and the time of hospitalisation reduced (Ulrich 1984, Frandsen et al. 2009, Ulrich et al. 2008).
There is therefore a great potential in regarding the healing process from a holistic approach, which also includes the physical environment.
In order to explore how textiles could contribute with aesthetic qualities in the hospital interior, I will relate to the concept of atmosphere in the next chapter, before presenting the findings of a case study, focusing particularly on the aesthetic qualities of textiles in health care architecture.

THE CONCEPT OF ATMOSPHERES

Seeking to accentuate and articulate how textiles can contribute with aesthetic qualities in the hospital interior, I will introduce the concept of atmosphere. This chapter is also relating to a part of the background study with a separate distinctive paper (Paper D), and the chapter will thus be a short summary of this paper, with the purpose of outlining the findings that are used in the following exploration of the aesthetic qualities of textiles.

The concept of atmosphere is often related to the immediate experience of space that may be explained as the unconscious response to the physical environment, as also explained by Pallasmaa (2001) and Küller (1991).
According to the German philosopher Gernot Böhme, the introduction of atmosphere in architecture and design research, has turned focus towards the experienced quality of space, understood as a holistic fusion of both physical and social design aspects (Böhme 2013a). Comparable to Küller's model of human-environment interaction (Küller 1991), the atmosphere is influenced by the physical environment of form, colour, light, acoustics, materials and texture, but also the social climate, cultural symbols and behavioural norms. All these different elements affect each other mutually and define the space and the architectural experience – the atmosphere (Böhme 2013a).
According to Böhme, atmospheres can thus be regarded as a new aesthetic concept that relates to the sensuous experience of space and design. Even though our language can skillfully define the atmosphere as joyful, serious, majestic, cold or cosy, the feeling of atmospheres is still peculiarly intangible. The atmosphere floats between the sensing human bodies and the physical objects of the surrounding space – between the subject and the object (Böhme 1998).
The experienced presence of atmospheres is naturally influenced by a personal sense, which evidently is difficult to support in large-scale public hospital buildings. Still the space has an objective constitution, which is not part of the personal sensitivity (Böhme 1998). According to Böhme, the experience of atmosphere is quasi-objective, understood as a subjectively based experience, we can communicate and discuss with others, and which is also relating to our cultural and sensuous aesthetic experience (Böhme 2013a, Böhme 2013b).

MATERIALS AND THE CONCEPT OF ATMOSPHERE

While Böhme's philosophical elaboration provides a fundamental understanding of the concept of atmosphere, the Swiss architect and practitioner Peter Zumthor, who in 2006 wrote the book ”Atmospheres – Architectural environments, surrounding objects”, can provide a more operational link between the aesthetic experience of atmospheres and the use of materials. In Zumthor's (2006) approach to the understanding of atmosphere, he has a strong emphasis on materials and the deliberate composition of their inherent qualities. In paper D, the 9 factors of atmosphere that Zumthor consider in his

Ill. 4.3 Photos from the Cancer Counselling Center in Herning, Denmark

Ill. 4.4 Photos from Ankerfjord Hospice in Ringkøbing, Denmark

approach to architecture are unfolded, and used as a framework for a design analysis of two case studies; a cancer counselling centre in Herning, Denmark (ill. 4.3) and a hospice in Ringkøbing, Denmark (ill. 4.4). In both cases, textiles have been used in the interior to provide a comfortable, warm and pleasant environment with familiar and recognisable references, which corresponds to the patients' request for more home-like environments and interiors (Danish Patients 2009, Lawson, Phiri & Wells-Thorpe 2003, Horsburgh 1995).

To avoid redundance, I will not present the case studies in detail in this thesis (see instead paper D), but rather summarise the findings, which have led to the establishment of a conceptual framework that accentuate the potential aesthetic qualities of textiles in the hospital interior.
Having analysed the cases (paper D), it becomes apparent that the textiles contribute with a range of different design qualities of both functional and aesthetic character that can also be used to improve the experience in hospitals (fig. 4.5).

Fig. 4.5 Conceptual framework - Aesthetic qualities of textiles

Case study findings *Interior textiles are:*	**Factors of atmosphere** *(Zumthor 2006)*	**Notes on contextual preconditions** *Case study findings related to the hospital context*
■ **Improving the acoustics**	*"The sound of space"*	Noise of medical equipment and other patients are challenging the need for calmness and rest, and the wish for private conversations. Acoustics are therefore traditionally an aspect of healing architecture (Frandsen et al. 2009).
■ **Providing flexible screens and shades**	*"The light on things"* *"Tension between interior and exterior"*	The possibility to control the physical environment is highlighted as an important aspect of healing architecture (Ulrich 1997), and controlling the daylight and diffuse light in the physical environment will affect the room atmosphere and the architectural experience.
■ **Defining zones and a sense of place**	*"The body of architecture"*	By virtuelly and physically defining smaller zones with textile based objects, a private place may be defined in the otherwise large scale hospital environments.
■ **Providing variability and changeability**	*"The body of architecture"*	Hospitals are today built as small cities and variability in different areas of the hospital may support wayfinding (Frandsen et al. 2009) and define the different wards and areas with a distinctive sense of space.
■ **Increasing the sensuous and tactile qualities (tactility)**	*"Material compatibility"* *"The temperature of space"*	Materials of hospitals today are often limitied to plastic, vinyl and gipsum. As a contrast material to these hard surfaced elements, textiles may balance the sensory perception of vision and touch. Also giving a warmer impression of the environment compared to the otherwise cold materials.
■ **Relating to homely references (familiarity)**	*"Surrounding objects"* *"Levels of intimacy"*	The interior objects of most hospitals are often promoting the institutional and clinical impression of the physical environment, and here textiles may relate to homely references and increase the levels of intimacy and human scale attempting to personalise the surrounding space.

As presented in paper D "Interior Textiles and the Concept of Atmospheres".

As the paper notes it is especially the sensuous tactile aspects, and the familiarity and recognisability of home-like environments that can contrast the existing institutional experience of contemporary hospital interiors. The tactility will be a contrast to the cold materials of vinyl, plastic and plaster that constitute the interior today, while the familiarity will provide references to home-like environments in opposition to the institutional atmosphere that imbue the interior today. Essentially, the other design aspects listed in the conceptual framework (fig. 4.5) may also the improve the hospital interiors, but I find 'familiarity' and 'tactility' in greatest contrast to the experience of hospital interiors today, and therefore these qualities can have the potentially greatest effect on the interior experience, when seen from a patient perspective. I will therefore direct my main attention towards these specific design qualities, and in the following two chapters further unfold the aesthetic qualities related to familiarity and tactility.

ESSENTIAL AESTHETIC QUALITIES OF TEXTILES - FAMILIARITY AND TACTILITY

In the case studies, familiarity and tactility were deduced as particular aesthetic qualities of textiles, which potentially could improve the patients' experience of the hospital interior. In the next two chapters, I will unfold these qualities theoretically, before presenting the hypotheses that are tested in the following experiments.

FAMILIARITY

Having analysed the cases, presented in paper D, recognisability or familiarity are emphasised as one of the central aesthetic qualities of textiles that affect the experienced atmosphere. The textiles are included in the interiors of the cancer counselling centre and the hospice, as recognisable objects and materials that provide a personal and human touch to the space, referring to well-known home-like environments. Relating to the 'level of intimacy' (fig 4.5), the experience of the public environment is thus balanced towards a less institutional and more accommodating atmosphere (paper D).

Considering the critique of contemporary hospitals as being clinical and institutional (Wagenaar 2006), or alienated, technological structures (Pallasmaa 2005), the concept of familiarity is particularly a lacking design quality. At the same time, patients are in studies and reports requesting more home-like environments (Danish Patients 2009, Lawson, Phiri & Wells-Thorpe 2003, Horsburgh 1995), which again relates to familiarity. This request for home-like environments has not yet been linked to the use of materials, as I elaborate on in the paper *"Home-like hospital environments - How furniture and materials in a refurbished hospital dayroom influence the patient experience"* (Paper F).
In paper F, the home-like perspective is further defined and discussed, and to avoid redundance, I will in the thesis simply summarise that home-like hospital interiors should not intend to provide copies of the patients' own homes, but rather provide accommodating interiors, where comfort, security and safety are experienced, and where the possibilities of physical and mental relaxation are facilitated.

Providing recognisable associations to home-like environments, interior textiles may be considered as a material of familiar and symbolic references, relating to the concept of 'symbolic aesthetics', which professor of architecture Jon Lang addresses in the essay "Symbolic aesthetics in architecture: Towards a research agenda" (Lang 1988). Referring to semiotics, Lang states that a symbol is something that connotes a meaning beyond its instrumental use, and many different architectural variables may thus carry symbolic meanings. Building configurations, styles and places may be symbolically associated with certain events, people or experiences, but also materials can provide a symbolic connotation (Lang 1988). Today, the interior materials of vinyl, steel and plastic are often chosen for their technical attributes, while textiles could provide

associations of less institutional atmospheres. Lang (1988) also addresses that there often is a conflict between the technical sensibleness and the symbolic aesthetic requirements in design, which particularly is pronounced when considering hospital interiors. The symbolic aesthetic qualities of textiles may thus be a reference to more familiar and home-like environments, which potentially could improve the patients' experiences of hospital interiors.

The aesthetic quality of familiarity also relates to the theory of 'knowledge structures' as put forward by professor Jack L. Nasar and Alan T. Purcell (Nasar, Purcell 1990, Purcell, Nasar 1995).
According to Nasar & Purcell, aesthetic experiences are the unconscious result of the differences between what is observed and the observers' existing knowledge structures. These knowledge structures are based on repeated experiences of regularities, and while small discrepancies between existing knowledge structures and the observed may increase interest and positive arousal, greater discrepancies will result in dislike and potential discomfort (Nasar, Purcell 1990). Knowledge structures are thus a non-conscious learning process that constructs a mental representation of the regularities in the spaces we perceive. When we perceive an object we evaluate whether this fits with our current knowledge structures, and a fit to an existing knowledge structure is associated with familiarity (Purcell, Nasar 1995). While most hospitals today may relate to a person's knowledge structure of a traditional hospital, a more familiar and accommodating interior could relate to knowledge structures of home-like environments instead. The link between existing knowledge structures and the perceived environment should thus be in harmony, and the design of accommodating and home-like interiors therefore require a particular focus on the use of interior materials to avoid too large discrepancies. Plastic upholsteries, as used in hospitals today, is from that perspective considered to conflict with the patients' knowledge-structures of home-like environments, challenging the design of improved hospital interiors.
Interior materials in hospitals are therefore essential to consider for their aesthetic qualities as well, as they have a certain effect on the experienced harmony and atmosphere of the space. Textiles could from a theoretical perspective thus build on the patients' knowledge structures as a symbol of accommodating, home-like environments associated with comfort, security and safety.

TACTILITY

Apart from the quality of familiarity, tactility was emphasised in the case studies as one of the main qualities of textiles that could contribute to an improved experienced atmosphere. In the cancer counselling centre and the hospice, the textiles provided a soft and comfortable contrast to the hard, cold materials that traditionally constitute the hospital interior. The textiles here contributed with a tactile quality, which is emphasised by Pallasmaa as a central aesthetic quality, which is often neglected in contemporary architecture.

> *”With the loss of tactility, measures and details crafted for the human body – and particular for the hand – architectural structures become repulsively flat, sharp-edged, immaterial and unreal. […] The flatness of today's standard construction is strengthened by a weakened sense of materiality.” (Pallasmaa 2005, p. 31).*

According to Pallasmaa, the tactile quality of architecture is important for our aesthetic experience of the physical surrounding, and in hospital interiors, textiles could thus provide this tactile quality that is neglected today (Pallasmaa 2005).
Citing Ashley Montagu's ”Touching: the human significance of skin”, Pallasmaa furthermore addresses how our skin is the most sensitive organ we have, and being the first sense to develop (Gallace, Spence 2011), touch is our first medium for communication with the surrounding world (Pallasmaa 2005, Montagu 1971).

The tactile experience of textiles relates above all to the sense of touch, which is essential in all our everyday experiences.
The researcher in psychobiology and multi-sensory integrations Alberto Gallace and professor in experimental psychology Charles Spence, who have done recent research on the sense of touch, elaborate on how these everyday experiences are depending strongly on the tactile experience. The sensation of being pressed against the seat when a sports car accelerates or being caressed by loved ones, would not be as enjoyable without the tactile dimension, and these experiences of touch thus constitute cornerstones in our social, cognitive and physical development as human beings (Gallace, Spence 2011).

Despite this essential influence of tactile experiences, there is only a few studies, which have explored the perception of tactile stimuli and the connection to emotional and aesthetic experiences (Essick et al. 2010, Rolls et al. 2003). In the study by Rolls et al. (2003), it was observed that different parts of the brain's orbitofrontal cortex were stimulated by painful or pleasant touch, and that the pleasant touch also stimulated a part of the cingulate cortex, which is an integrated part of the limbic system that is involved in emotional processes.
That the tactile touch is stimulating the part of the brain that is related to emotional experiences is particular interesting as the findings suggest that tactility is also

neurologically linked with emotional and aesthetic experiences (Rolls et al. 2003).
The tactile touch is registered through receptors on the skin, which detect touches, vibrations, cold, heat and pain (Gallace, Spence 2014). Our evaluation of the touch is however experienced in a multi-sensory interplay with our other senses, and the experience of touch may thus be regarded quite differently although the same tactile receptors have been affected. Gallace and Spence exemplify this by comparing the touch by a family member and being involuntarily nudged by a stranger's bag in the underground, which will not produce the same emotional experience (Gallace, Spence 2014).

The tactile experience can relate to a micro-geometric and macro-geometric scale, where the micro-geometric scale relates to the surface structure, while the macro-geometric scale refer to the objects size, form and construction (Gallace, Spence 2014). Concerned with the use of textiles for hospital furniture, the macro-geometric structure would more or less be the same independent of the chosen upholstery, while the micro-geometric experience will change significantly if plastic or traditional textiles are used. In the experiment at Hospital Vendsyssel (paper E), where the patients were presented with physical test samples of different types of upholstery, they all grasped the textiles and judged their micro-geometric properties in terms of textile handle, friction, structure and weight.

When the upholstery afterwards are installed on the chair, it can be discussed whether the micro-geometric, tactile experience will be as pronounced, when we sit fully dressed in a chair, at for instance, the hospital. The fine structure of the textile material may be distinguished from each other, when we sit with the different materials in our hands, but it is more doubtful that we can distinguish the material through a pair of jeans. However, the textiles will still provide some essential sensuous qualities to the experience of space.
Today, the plastic coated textiles are used in the hospitals instead of textiles, and even though the tactile receptors will not register a particular difference between the plastic and the textile upholstery, our multi-sensory experience will still instinctively reveal which kind of chair we are sitting in. The sound will be different, when our body is pressed against the soft textile compared to the harder plastic, and the friction between the body and the seat will be felt differently. The textured surface of the textiles will often secure a firm hold, while the plastic material will make the person slide downwards and require a frequent repositioning. Furthermore the physical properties of the materials in regards to thermal conductance and air permeability, makes the plastic material feel cold in the beginning, before it changes to a warm and moist experience of poor breathability. Together these multi-sensory experiences will be an extension of the tactile experience, and we will instinctively have an expectation to the feeling of sitting in the chair, already when we see it.

Architectural theoretician, Steen Eiler Rasmussen, is in his description of throwing a stone, relating to this unconscious expectation of the experience. Having held a stone in the hand through many previous occasions, we instinctively know how any stone will

feel in the hand just by looking at it (Rasmussen 1966). Compared to textiles, a study by Picard et al. (2003) on the perceptual dimension of tactile textures, also showed that the group of respondents could as easily describe the tactile qualities of textiles from their memory, as when they had the textiles in their hand.

This connection between the tactile and visual sense through our memories and expectations is considered essential and central in the understanding of the textiles aesthetic qualities in architecture.

Pallasmaa also relates to this importance, as he refer to art historian Bernard Berenson:

> *"Bernard Berenson suggested that when experiencing an artistic work, we imagine a genuine physical encounter through "ideated sensations". The most important of these he called "tactile values". In his view the work of authentic art stimulates our ideated sensations of touch, and this stimulation is life-enhancing. Indeed, we do feel the warmth of the water in the bathtub in Pierre Bonnard's paintings of bathing nudes and the moist air of Turner's landscapes, and we can sense the heat of the sun and the cool breeze in Matisse's paintings of windows open to a view of the sea." (Pallasmaa 2005 p. 44).*

Tactility and the sense of touch have thus an essential affect on our experience of the physical environment, even though our tactile receptors are not directly affected.

> *"Vision reveals what the touch already knows. We could think of the sense of touch as the unconscious of vision. Our eyes stroke distant surfaces, contours and edges, and the unconscious tactile sensation determines the agreeableness or unpleasantness of the experience. The distance and the near are experienced with the same intensity, and they merge into one coherent experience."(Pallasmaa 2005 p. 42).*

Micro-geometric, tactile qualities provide an important sensory impulse that is essential in our aesthetic experience, and as tactility is neglected in most hospitals today, textiles could provide this dimension to the hospital interior, and improve the surroundings with essential aesthetic qualities.

BACKGROUND STUDIES – SUMMARY AND HYPOTHESES

AESTHETIC QUALITIES OF TEXTILES

Through the first chapters in the aesthetic part of the project, I have combined different approaches to unfold some of the aesthetic qualities of textiles, which I consider could contribute to the patient's experience of the hospital interior. The concept of atmosphere has been used specifically to accentuate some of these qualities, and familiarity and tactility have been deduced as aesthetic qualities with a particular potential when concerned with contemporary hospital interiors. Here the textiles' symbolic associations and home-like familiarity can provide a contrast to the institutional and clinical atmosphere, which characterise most hospitals today, while the tactile quality can contrast the hard, cold surfaces of plastic, vinyl and steel. There is naturally a range of other aesthetic qualities, where only some of them are presented in the conceptual framework in paper D. Even though these qualities could provide an essential effect as well, I have chosen to focus on only two of them (familiarity and tactility), due to the dimension of this PhD thesis. Based on the background studies, which accentuate and articulate how the aesthetic qualities may improve the patients' experience of the hospital interior; I will define two main hypotheses for testing in the following experimental studies. These experimental studies seek to relate the theoretical perspective, to the patient perspective through empirical inquiries.
The experimental part will contextualise the qualities of textiles in regards to the patients' experience of the hospital interior, seeking to explore the hypotheses as stated.

Hypothesis 1:

> *The patients will have a preference for textiles in the hospital interior.*

Motivation:
Concerned with the immediate aesthetic qualities of textiles, and the direct request by patients for more home-like interiors, it is expected that the patients will have a preference for textiles in future hospital interiors.

Hypothesis 2:

> *The patients will experience the atmosphere as being more accommodating when textiles are introduced to the hospital interior.*

Motivation:
The aesthetic qualities of home-like familiarity and tactility will affect the patients' experience, and they will consider the space more accommodating and home-like, when textiles are applied.

EXPERIMENTAL STUDIES

The experimental studies will explore the two hypotheses raised on the basis of the theoretical background studies. As mentioned in the methodology chapter, these experiments will have an exploratory nature and seek to relate the theoretical perspective to the patients' concerns through empirical inquiries.

The first study will direct the patients' immediate preferences for materials and furniture in a hospital interior, while the second study will focus on the patients' experiences in a refurbished hospital dayroom. Together these two studies will provide an insight in how the patients perceive and experience textiles in hospital environments.

The experimental studies is presented in the two papers *"Interior design and healing architecture: A mixed-method study on the patients' preferences for interior textiles and textile-based furniture for future hospitals"* (Paper E), and *"Home-like hospital environments - How furniture and materials in a refurbished hospital dayroom influence the patient experience"* (Paper F). In this result section I will present the two studies with a short introduction stating the background and purpose of the study, and then highlight the main results before discussing the perspective of these findings.

STUDY E – PATIENTS' PREFERENCES FOR TEXTILES AND TEXTILE-BASED FURNITURE

The first experimental study relates to the hypothesis that patients will have a preference for textiles and textile-based furniture in the hospital interior. Concerned with the immediate aesthetic qualities of textiles, and the patients' direct request for more home-like interiors (Danish Patients 2009, Horsburgh 1995, Lawson, Phiri & Wells-Thorpe 2003), it is expected that the patients will have a preference for textiles in future hospital interiors.

Preference studies

In regards to the construction of new hospitals in Europe and the U.S., the experience of being hospitalised has come in focus, and the patients' wants, needs and preferences are acknowledged (Bromley 2012, Lawson 2010). From a design perspective, this new awareness on the patients' experiences has changed the way of planning and designing hospitals, and the patients' preferences for hospital design have been addressed in a wide variety of recent studies on: art (Carpman, Grant & Simmons 1993, Ulrich 1991, Frampton, Gilpin & Charmel 2003); colours (Dalke et al. 2006), windows and views (Verderber 1986); ward design (Pattison, Robertson 1996, Rowlands, Noble 2008); meals (Holm 2003); hospital gardens (Whitehouse et al. 2001, Barnhart, Perkins & Fitzsimonds 1998); children's wards (Nanda et al. 2009, Eisen et al. 2008, Coad, Coad 2008); and adolescents' environments (Blumberg, Devlin 2006, Miller, Friedman & Coupey 1998, Ullán et al. 2012).

However, despite this general focus on the patients' preferences, knowledge on the use of materials and furniture in hospital interiors is still rather limited (Douglas, Douglas 2004). Existing literature suggest that a more 'home-like' environment is preferred to support the patient-friendly experience (Horsburgh, 1995; Lawson, Phiri and Wells-Thorpe, 2003), but the term 'home-like' has not been linked to the use of materials in hospital interior solutions. Previous studies within hospital design suggest that the first step to improve the patients' experience is to ask them about their preferences (Britto et al. 2004, Ullán et al. 2012), and to gain initial knowledge on the patients' concerns regarding hospital interior design and the use of textiles, this study explored their preferences for interior design furniture and materials.

Purpose

To compliment research in the field of hospital interior design, the experimental study has addressed focus on the use of textiles in hospital interiors, and have explored if the patients' general preference for home-like interiors could be linked to a preference for interior textiles and textile-based furniture.

As described in the paper and methodology chapter, the study was conducted as a mixed-method study, where 43 patients at the outpatient lung department at Hospital Vendsyssel, Hjørring were asked about their preferences for furniture and materials, based on pictures of 5 different armchairs and test samples of 5 different types of upholstery (see paper E and the research methodology chapter p. 49 for details). Furthermore the patients were asked about their experience of the general hospital interior.

Findings

The study was divided in a quantitative and a qualitative part, relating to the mixed-method approach in the study, and in paper E, the results are presented in detail. In the thesis I will summarise the results and discuss the findings that has progressed the PhD study.

As paper E describes, most patients in the study, preferred the typological hospital chair, and only a small group preferred the textile-based furniture. This preference disproves to some extend the hypothesis that patients would prefer textiles in hospital interiors, and the preference for the hospital chair was thus an immediate surprise.

Ill. 4.6 The chair that most patients prefer for a future hospital dayroom. (See other chairs and description in fig. 2.10 p. 49)

The patients explained that they found the chair appropriate for the hospital interior, and some even expressed that they found the textile-based armchairs too luxurious for the hospital environment. When asking the patients how they experienced the existing interior at the hospital, a large group of the patients expressed a distinct satisfaction towards the current design. The qualitative results, however, indicated that this satisfaction might be linked to the patients' confined design expectations, and as some patients mentioned they were satisfied as long as a chair and table was available.
Dividing the patients in two sub-groups depending on their interior design satisfaction therefore provided some interesting perspectives on the preference diversity.

Fig. 4.7 Patients' preferences for furniture and materials for future hospitals

Furniture

	General interior design			
	Satisfied		*Request improvements*	
	n	(%)	*n*	(%)
Chair 1	23	(67,6)	1	(11,1)
Chair 2	6	(17,6)	2	(22,2)
Chair 3	1	(2,9)	2	(22,2)
Chair 4	2	(5,9)	2	(22,2)
Chair 5	2	(5,9)	2	(22,2)

Materials

	General interior design			
	Satisfied		*Request improvements*	
	n	(%)	*n*	(%)
Mat. A	11	(32,4)	1	(11,1)
Mat. B	8	(23,5)	3	(33,3)
Mat. C	10	(29,4)	4	(44,4)
Mat. D	2	(5,9)	1	(11,1)
Mat. E	3	(8,8)	0	-

As presented in paper E "Interior design and healing architecture: A mixed-method study on the patients' preferences for interior textiles and textile-based furniture for future hospitals".

The group of patients, who was satisfied with the existing interior, had a strong preference for the typological hospital chair, while the patients, who requested interior design improvements, preferred the textile-based armchairs instead. The same tendency appeared, for the upholstery materials, where the patients, who were satisfied, had a strong preference for the plastic upholstery (material A), while the patients, who requested interior design improvements, preferred the traditional textiles.
As the group of patients, who request improvements can be related to existing literature, where patients request more accommodating and home-like interiors, their concerns are particularly relevant in regards to the question on whether the preference for home-like interiors can be linked to a preference for interior textiles. Despite the limited group of patients, who express this preference, the study however provides certain indications, which confirm the connection between a preference for home-like interiors and a preference for interior textiles.

The group of patients, who were satisfied with the existing interior and preferred the traditional hospital chair, was also interesting as a phenomenon. In the paper I discuss that the patients' confined expectations towards the interior may have affected their preferences, which is also addressed by Bate and Robert (2007). Concerned with experience-based design, they advocate that due to patients' low baseline expectations, high satisfaction ratings is not a sufficient reason for not seeking to improve the patient experience. *"The lower the expectation, say of a health service, the more 'satisfied' one*

is likely to be with it (and, equally, the higher the expectation, the greater the likelihood of disappointment or dissatisfaction." (Bate, Robert 2007, p. 3) Accordingly, to provide experience-based design for future patients, their expectations should be exceeded (Bate, Robert 2007).

When considering the experimental study retrospectively, the patients' existing knowledge structures may also have influenced their stated preference. The interviews were conducted in an existing patient waiting room, and although the patients were asked about their preference for a future dayroom, the existing interior may have influenced their stated preference. For some patients, it may have been difficult to imagine future design changes, and they may thus have chosen the chair, which corresponded with their existing knowledge structure of a hospital environment.
The rooms general composition may thus have affected the patients stated preference, and it can be discussed whether the methodological setup has been appropriate for the study. If the study had been conducted in a refurbished dayroom, where textiles were already present, the results would probably have been different. Furthermore the patients only visited the hospital for a short period of time, and their needs for a more accommodating interior could have been different if they had been hospitalised and had stayed in the hospital for a longer period.

Summary

The study was initiated to gain knowledge on the patients concerns regarding textiles and textile-based furniture for a hospital interior, and although the hypothesis that patients preferred textiles only was confirmed for a smaller part of the respondents, the study have provided an insight in the patients interior design concerns.
As discussed, the methodology of asking patients about their preferences in a traditional hospital environment may not have been the right approach, and the statement that 'the first step to improve the patients' experience is to ask them about their preferences' (Britto et al. 2004, Ullán et al. 2012), is therefore questioned. Although preference studies may provide initial knowledge on the patients' concerns regarding certain aspects, different types of studies are needed to fully explore the patients' *experiences*.
As introduced, there have been a wide variety of preference studies on hospital design, but as I conclude in the paper there might be a value in changing focus towards the patients' experiences rather than preferences. From that perspective, design-based studies as for instance full-scale mock-ups, would most likely be a more appropriate method to gain knowledge on the patients' experiences of the interior.
In the next experimental study, the point of departure will thus be a design experiment, where the patients' experiences of a refurbished hospital dayroom have been analysed and discussed.

STUDY F – PATIENTS' EXPERIENCES OF A REFURBISHED HOSPITAL DAYROOM

The second experimental study relates to the hypothesis that patients will experience the hospital dayroom as more accommodating if textiles are introduced to the hospital interior. The study also builds upon the knowledge gained in the experiment, where patients were asked about their preferences. In this study the methodological setup will thus be based on a full-scale mock-up at Odense University Hospital (OUH). The study is also presented in paper F, and the presentation in the thesis will be a shorter summary, where the findings are highlighted.

Home-like hospital interiors

As already mentioned, research on the use of materials and furniture in hospital interior design is limited (Douglas, Douglas 2004), and the few studies that has been conducted only suggest that patients request and prefer more home-like environments (Caspari, Nåden & Eriksson 2007, Danish Patients 2009, Lawson, Phiri & Wells-Thorpe 2003), without considering the physical dimensions of this home-like experience. In the paper, I establish that the home-like experience, however also links closely to the use of materials, furniture and objects that generate the room atmosphere, and facilitates the behaviours in the room. The paper then elaborates on how the term home-like could be interpreted in regards to the context of hospitals. I will refer to the paper for this elaboration, and in the thesis summarise that the home-like hospital environment could be accomplished by designing spaces, where comfort, security and safety is experienced, and where the possibilities for physical and mental relaxation is facilitated. Concerned with this design brief, the hospital furniture and materials are considered of essential importance. Not just as physical objects, but as associable recognisable symbols that may communicate certain references and atmospheres.

Purpose

Concerned with the immediate potential of textiles in hospital interiors, the study sought to unfold the patients' experiences of a refurbished hospital dayroom and gain knowledge on how a more home-like hospital atmosphere affects the patients' experience of the interior. As described in the methodology chapter, the study was conducted at the Nephrology department at Odense University Hospital, where the dayroom was refurbished for a three-week period, with particular focus on defining a more home-like environment by using textiles, amongst others. The methodology is described more thoroughly in the methodology chapter and in the paper (Paper F). The pictures (Ill. 4.8 and 4.9) illustrate the dayroom before and after refurbishment, which was done in cooperation with designers at the Health Innovation Centre of Southern Denmark.

Ill. 4.8 Photos of the existing interior at the Nephrology department, OUH.

Ill. 4.9 Photos of the refurbished interior at the Nephrology department, OUH.

Findings

For two days the patients were passively observed in the refurbished dayroom, before interviews with 4 hospitalised patients and the ward nurse were conducted. Aiming to explore the patients' experience, the results have been summarised in three overall themes that combines data from the observations, patient- and staff interviews. The themes are presented and discussed more thoroughly in the paper, and I will here summarise the key findings of the three themes.

The perceived interior atmosphere

The patients generally experienced the refurbished dayroom as a comfortable environment, and the 4 patients that participated in the interview all related to the dayroom as a home-like environment. As the dayroom was considered remarkable different than the rest of the hospital, the area was experienced as a place for quiet relaxation, but also as a place that facilitated social company with other patients or family visitors. The ward nurse confirmed that the patients had a very positive experience of the dayroom.

Materials as home-like references

As described in the methodology chapter, and illustrated in the pictures (Ill. 4.8), the room was refurbished by using textiles as upholstery, curtains and accessories like cushions. However, the room changes also included the application of other home-related references like books, wall paper, candles and flowers, as well as the furniture was rearranged to define smaller, more intimate, seating situations. With all the different design changes that constitute a multi-sensory and holistic experience (Pallasmaa 2001), it is naturally difficult to isolate the textiles and define their contribution to the patients' experience. However, to address focus on the patients' concerns regarding the use of materials, the patients were asked a few questions on how they perceived the different changes in the room, including the use of upholstery. The patients here described that the textiles promoted the cosy and relaxing experience, and one of the patients had a good description of her impression of the new upholstery:

> *"It [the upholstery] is extremely pleasurable, when it is so 'warm' and structured. It is a pleasure for the body to be met by [a material like this]. Normally, we are sitting in bed linen the entire day sliding around, but when your body hurts it is comfortable to sit in materials like these instead." (Female patient, 56 years).*

The textiles were thus compared to the traditional hospital materials, which did not provide the same tactile comfort or reference to home-like environments. As the nurse also emphasised:

> *"You would never choose a chair or a sofa in plastic upholstery for your home, as we normally do here, so it provides a different experience. You will feel more like home in a room with textiles." (Nurse).*

Through the observations and interviews with patients and staff in the hospital dayroom the aesthetic qualities of textiles became evident and both familiarity and tactility were emphasised as distinctive qualities.

Patient behaviour

The third and final theme was related to the patients' behaviour in the refurbished dayroom. Patients were observed to have different and more relaxed seating postures in the more home-like environment, and some patients even took of their shoes and was taking a nap on the couch or watched television. Behaviours that are associated with everyday activities in our private homes, but which are rarely seen in the hospital environment.
In the interviews one of the chronic patients, who had been at the ward many times before, also stated that she had never used the dayroom before, but that she was now visiting the dayroom every morning. According to the ward nurse this behavioural pattern was confirmed as a general tendency, where patients that previously had been lying in their bed, now was seen more motivated to visit the dayroom.
The projects limited time frame of three weeks have not been enough to provide significant evidence of this apparent increase of patient mobility. However, if the indications can be confirmed in a prolonged study, the value of refurbishing hospital dayrooms could be remarkable, as the mobility is related strongly to patient outcomes as discussed in paper F.

Summary

The study on patients' experiences in a refurbished hospital dayroom confirms the second hypothesis that patients will experience the hospital dayroom more accommodating if textiles are introduced to the hospital interior. Although the positive experience is related to the holistic perception of the room, textiles were mentioned and emphasised as important design changes by the patients and the nurse during the interviews. The home-like atmosphere was emphasised by all patients during the interviews, and the theoretical perspective of familiarity is considered related to this experience. The tactile quality of textiles was also highlighted by the patients as a needed contrast to the traditional hospital materials, and the observations showed more relaxed seating positions which also may be related to the unconscious tactile experience of the traditional textiles.
Furthermore, the method of conducting a full-scale mock-up study has proven appropriate for exploring the patients' experiences. While more than 50 % of the patients in

the previous study on the patients' preferences preferred the traditional hospital chair, none of the patients have expressed a scepticism towards the new home-like and textile-based interior in the mock-up design study. The study has provided a valuable insight in the patients' experiences of textiles in hospital interiors, and as the findings also indicate that the patients' mobility could be motivated by improving the hospital interiors, future studies should be conducted to provide more significant evidence of this observation.

CONCLUSION - AESTHETIC PART

The aesthetic part of the project has explored some of the ways that textiles can contribute with aesthetic qualities in hospital interiors, and how these qualities affect the patients' experiences.
Having combined the theoretical background studies that accentuated and articulated the aesthetic qualities of textiles with empirical experimental studies, which related the theoretical perspective to the context of hospitals and the patients' experiences, the project have sought to provide new knowledge on the aesthetic qualities of applying textiles in future hospital interiors.

Aesthetic qualities may be neglected in most contemporary hospitals, but linking to our well-being and health, there is a substantial potential in improving the aesthetic dimension of hospital interiors (Cold 2001). As the theoretical studies suggest, the familiar and tactile qualities of textiles could from this perspective assist in providing a more accommodating and patient friendly atmosphere in the hospitals. The aesthetic dimension of the physical environment has an enormous effect on our experience and behaviour (Küller 1991, Nasar, Purcell 1990, Purcell, Nasar 1995, Lang 1988), and when this dimension is not supported, we are in risk of being stressed or even sick (Pallasmaa 2001, Ulrich et al. 2008, Küller 1991). Today the hospitals are often experienced as institutional (Wagenaar 2006) and alienated technological structures (Pallasmaa 2005), while a more accommodating interior could provide aesthetically pleasing environments that potentially could reduce the patients' level of stress, as presented in research on healing architecture (Frandsen et al. 2009, Ulrich et al. 2008, Dirckinck-Holmfeld et al. 2007).
The concept of atmosphere have been used as a conceptual framework for accentuating the aesthetic qualities of textiles in two case studies of Danish health care architecture, and based on these findings, familiarity and tactility were deduced as two central themes and qualities that could contrast the current hospital interiors and provide a more patient-friendly atmosphere. Having further unfolded these aesthetic qualities, the background study summarised two main hypotheses for testing in the empirical experimental studies.
While the first experimental study provided an insight in the patients concerns regarding hospital materials, and suggested that preferences for home-like environments can be linked to preferences for interior textiles, the appropriateness of preference studies were questioned as the right method to explore the patients' experiences. The final experiment was instead conducted as a full-scale mock-up, and in the refurbished hospital dayroom at Odense University Hospital, the patients' experience was explored and unfolded through observations and interviews.
The patients generally experienced the dayroom as a home-like, accommodating environment, and based on the interpretations of the interviews, the aesthetic qualities of familiarity and tactility could be related to the patients' experiences and statements. Furthermore the patient mobility seemed to be motivated by the improved hospital interiors, which would be essential to further explore in prolonged experimental studies.

The main purpose of the aesthetic project part, as to accentuate and articulate the aesthetic qualities of textiles in hospital interiors, has with the theoretical and empirical studies been conducted. As mentioned, other aesthetic qualities could evidently be accentuated as well, but concerned with the context of hospital interiors, familiarity and tactility were found particularly relevant in order to improve the hospital atmosphere and the patient experience.

With this summary of the aesthetic part of the project, I will in the following conclusion combine the technical and aesthetic aspects in an integrated model, and reflect on the qualities of textiles in hospital interiors from a cross-disciplinary perspective.

CONCLUSIONS AND REFLECTIONS

CONCLUSIONS

In the technical and aesthetic parts of the project, I have already concluded on these particular issues respectively, but in order to emphasise the importance of integrating the technical and aesthetic aspects, this concluding part of the project will summarise the findings and present them in an integrated model. By revisiting the overall purpose of the project and research question, I will relate the findings of the individual studies to the project's overall concern.

The project departed from the observation that despite the increased focus on the design concept healing architecture, newly built and planned hospitals are still designed and furbished with hard-surfaced standard materials like vinyl, plastic, gypsum and steel. The intentions of providing accommodating, inspiring and even home-like hospital interiors thus seemed challenged by the availability of materials for the hospital furniture and interiors in general.
At the same time, the development in material technology had proposed new types of hydrophobic textiles that might provide cleaning-friendly solutions to the hospital environment. These functional textiles were immediately corresponding to the request for more efficient cleaning processes at the hospital, but despite the potential, the materials were not yet used in the hospital interiors.
To progress the field of hospital design research and to improve the patients' hospital experience, the cross-disciplinary PhD project was initiated. By combining the aesthetic aspects of hospital surroundings, with the technical requirements for rational hospital cleaning processes, the overall purpose of the project has been to explore and accentuate the possibilities and design qualities of using functional textiles in the interior of future hospitals.

The overall research question for the project, sought to frame this cross-disciplinary and exploratory nature of the project by questioning:

> *What are the technical possibilities of using functional textiles in Danish hospital interiors, and how can interior textiles contribute with aesthetic qualities that promote the patients' experience of the hospital interior?*

To conclude on this overall research question, I will in a short summary list the main findings from the technical and aesthetic project part, respectively, before presenting the results in an integrated model.

FINDINGS – SUMMARY

TECHNICAL FINDINGS

Technical finding 1:

> *Functional textiles can be used in Danish hospital interiors, if they can be cleaned and disinfected properly and efficiently.*

Motivation:
There exists a range of different functional textiles with hygiene improving properties that may be used in hospital interiors, including antibacterial textiles and hydrophobic textiles. In Denmark, the hospital service departments and Statens Serum Institut [The National Serum Institute], who is the main national counsellor of hospital hygiene and infection control, caution against the use of antibacterial textiles due to the risk of increased bacteria resistance. Instead, the hydrophobic textiles, which provide a water- and dirt repellent surface that is easy to clean, can be used in Danish hospitals, if they can be cleaned and disinfected according to the national guidelines and standards of hospital infection control.

Technical finding 2:

> *The textiles can be cleaned in daily practice, and common types of liquid-based soils can be removed by standard cleaning methods.*

Motivation:
In a practice related study conducted at Hospital Vendsyssel, Hjørring, the ability to clean the hydrophobic textiles in daily practice was explored. The pilot-study results showed that the textiles could be cleaned by a standard hospital cleaning method, and that the bacteria level on the textile surfaces was below the critical limit value of microbiological evaluation after cleaning. In a following laboratory study, the ability to remove common types of soils was examined. While the fat-based stain was not possible to remove, the liquid-based soils of coffee and blood were removed completely by the standard cleaning methods.

Technical finding 3:

> *The textiles can be disinfected efficiently by the use of an alternative disinfection technology.*

Motivation:
Traditional textiles need to be laundered for disinfection, and as this process is time-consuming and expensive, the hospital service departments use alternatives for

furniture upholstery. To explore if new disinfection methods could be an efficient alternative for textile disinfections, the SonoSteam technology was tested. The study showed that the combination of steam and ultrasound efficiently could disinfect the textiles, and that the bacteria reduction was close to 100 % for all the different textile samples. The method is thus considered appropriate for the disinfection of textiles and hospital furniture, if new logistic processes for organising the disinfection can be developed and implemented.

Technical finding 4:

> *The hydrophobic coating is durable against abrasion, and complies with the demands for use in hospitals.*

Motivation:
In most cases, the hydrophobic properties of textiles derives from a finishing or coating, and to test if this coating could withstand the abrasion that comply with use in public areas like the hospital, the coatings durability was examined. The laboratory study showed that the water repellent properties of the textiles were maintained until 40-60.000 Martindale, which is well above the minimum requirement of 25.000 Martindale, which the Danish Technological Institute defines for hospital interiors.

AESTHETIC FINDINGS

Aesthetic finding 1:

> *Aesthetic qualities potentially link to the patients' well-being and health and should be an essential aspect of hospital interior design.*

Motivation:
Although neglected in some contemporary hospitals, the aesthetic qualities of hospital interiors affect the patients' design experience and behaviour. Today hospitals are often criticised of being too institutional and clinical in their physical appearance, which may increase the patients' level of stress and anxiety. Environmental psychology and the design concept of healing architecture, however, suggest that accommodating and inspiring physical environments reduce the level of stress and even support the patients' healing process.

Aesthetic finding 2:

Textiles provide aesthetic qualities of familiarity and tactility to improve the atmosphere of hospital interiors.

Motivation:
Based on the concept of atmosphere, familiarity and tactility were deduced in a case study as two central aesthetic qualities of textiles that could contrast the current interior of most hospitals and provide a more patient-friendly atmosphere. Other qualities relating to acoustic improvements, controlling daylight, defining private zones, and providing variability were also related to the use of textiles in hospital interiors. However, familiarity and tactility, were considered as essential qualities that could improve the patients' experience by providing a remarkable contrast to the institutional and hard-surfaced hospital interior, observed in many contemporary hospitals.

Aesthetic finding 3:

Textiles are preferred by the patients who request interior design improvements.

Motivation:
In a mixed-method study, the patients' preferences for hospital furniture and materials were explored. In literature and reports, patients generally request more home-like interiors, and the study intended to explore if this preference for interior design improvements could be linked to a preference for textiles in hospital interiors. The patients' stated preferences divided the group of respondents in two, where a small group confirmed that a preference for improved interiors could be related to a preference for textile-based furniture and materials. However, the majority of the patients expressed a preference for the traditional hospital furniture, and stated that they were satisfied with the existing hospital interior. Reasons for this satisfaction and preference might be linked to confined expectations towards the hospital interior. From that perspective, the method of conducting preference studies was discussed, as the patients' expectations controlled the level of satisfaction and the stated preferences. A full-scale mock-up study was thus proposed as a more appropriate method to explore the patients' experience of design aspects.

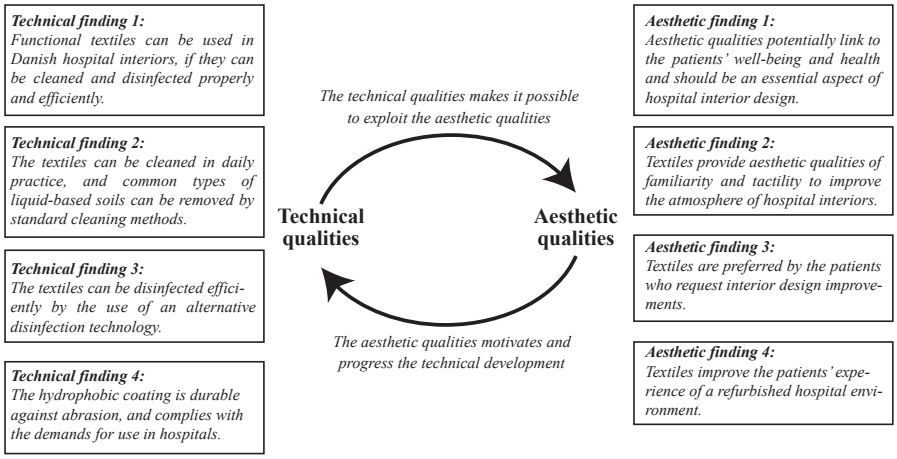
Aesthetic finding 4:

Textiles improve the patients' experience of a refurbished hospital environment.

Motivation:
In the final study on the aesthetic qualities of textiles, a dayroom at the Nephrology department at Odense University Hospital was refurbished, and textile-based furniture, curtains and accessories were applied to the hospital room. Patients were observed and interviewed in the new setting, and both patients and staff described the dayroom as home-like and accommodating. The aesthetic qualities of familiarity and tactility could through these interviews be related to the patients' experiences, and the patients were more motivated to use the dayroom with the new refurbishment.

INTEGRATED MODEL

Fig. 5.1 Integrated model of design qualities of textiles for hospital interiors



In the model above, the design qualities are summarised, providing an integrated response to the overall research question of the project. As the model illustrates, the aesthetic and technical aspects are interrelated, emphasising that the use of functional textiles in hospital interiors is based equally on the technical and aesthetic qualities. The textiles need to comply with the requirements for hospital hygiene, so the use do not compromise patient safety. At the same time, the materials should support the patients' experience of an accommodating hospital interior, relating to the visions of the design concept healing architecture. The aesthetic and technical qualities are thus of equal standing, and the relationship depends on each other. As the technical results show, there are still issues and challenges to be addressed in future studies, and to progress this technical development, the aesthetic design qualities of textiles can be used as motivation for this development.

As the project findings suggest, the functional textiles may support the current standards and guidelines of hospital infection control, and in the experimental studies, the cleaning and disinfection ability of the hydrophobic coatings performed well according to the hospital standards. The aesthetic qualities, which have been accentuated and articulated in theoretical background studies, were confirmed in the exploratory experimental studies. The patients at Odense University Hospital experienced the hospital environment more accommodating and inspiring, when textiles were introduced to the dayroom as furniture, curtains and accessories. The dayroom was described as home-like referring to the qualities of familiarity, and the patients regarded the tactile quality of textiles as a needed contrast to the traditional hospital materials.

Having summarised the findings of the technical and aesthetic parts of the project in an integrated model, I will in the following section reflect on the findings and propose future studies to further progress the development within the field of functional textiles for future hospitals.

REFLECTIONS
AND FURTHER STUDIES

The initiating hypotheses that were raised in the introduction of the project, which stated that textiles in hospital interiors would support the patients' experience of the hospital interior, and that functional textiles would comply with the requirements for hospital hygiene, have through the project been consolidated.

The project thus becomes another research study in the field of hospital design research that direct focus on a *single aspect* of the patients' *holistic* experience of design. This relation between research on single design parameters in regards to the integrated design solutions has been discussed earlier in relation to hospital design research (Shepley 1997, Shepley 2006, Stankos, Schwarz 2007, Vinding et al. 2011, Lawson 2010). Professor of architecture Bryan Lawson (2010) discusses this tendency further, and emphasise that although research tends to focus on these individual design elements, such as lightning, views, acoustics, or in this case textiles, solving *one* problem at the time is unlikely to result in good architectural quality. As Lawson emphasise all these design elements should be integrated holistically in the design process, which require a good design team in realising the research findings in practice. Installing or implementing textile materials alone will therefore not necessarily improve the patient outcomes per se, but should be combined with other design improvements to provide a holistic and harmonious experience. As this PhD project identifies, textiles may thus contribute with certain design qualities to improve the holistic experience of the hospital interior and thereby support the patients' healing process. Knowledge on the use of these familiar, home-like and tactile materials has therefore been addressed by this PhD thesis.

The project have explored and accentuated the possibilities and qualities of using functional textiles in the interior of future hospitals, and the aim of providing new research-based knowledge to inform practice and decision-makers in charge of designing and refurbishing hospital interiors has been initiated. In this final part of the project, I will elaborate on this practice-related aim, and discuss whether the decision-makers, with the results of this project, have the necessary background knowledge for making decisions on the use of functional textiles in future hospital interiors.

EVIDENCE-BASED HOSPITAL DESIGN

Hospital architecture has, since the first hospital was built in Denmark in Copenhagen in 1757, been based on the best knowledge accessible. In 1757 the knowledge about human biology and medical treatment was very limited, but the hospital constituted a physical gathering point for diseased citizens and had an important societal purpose. With limited medical knowledge to inform the design process, the task of designing the hospital was predominantly assigned to the architect, who developed the concept

based on aesthetic considerations and compositions (Dirckinck-Holmfeld et al. 2007). The *aesthetics* of the hospital were based on the human scale, detailed proportions and access to nature, and the hospital was in operation for more than 150 years. In the beginning of the 20th century, the pavilion hospital 'Rigshospitalet' was designed and replaced the old Frederik's Hospital of 1757, and by dividing patients in separate groups and allowing daylight and fresh air into the buildings, the intention was to address the emerging hygiene concerns and to reduce cross contamination. Since then medical knowledge has increased tremendously, and when constructing many of the current hospitals in the 1960's and 1970's, the rational focus on medical treatments had reached a level, which to some extent disregarded the patients' emotional values and concerns. Patients were considered a diagnosed object, which needed treatment according to the best accessible medical knowledge, and the hospitals were designed as 'machines for treatment', compacting the hospital functions in high-rise buildings to provide more efficient working procedures for the medical staff (Dirckinck-Holmfeld et al. 2007). Infatuated by the emerging medical possibilities, the aesthetic dimensions of hospital architecture and design became less important and sometimes completely neglected. However, in regards to the construction of new hospitals, design and architecture have re-gained its importance as a facilitator for the patients' holistic healing process. This re-introduction of the architecture's role for patient healing seem to be related strongly to the emergence of the design concept healing architecture, which have provided research-based 'evidence' on the correlation between good design and improved patient outcomes. Thus, when the hospitals today are designed with increased focus on daylight, nature, acoustics, etc., it is fundamentally caused by the contribution of research on the design and architectural influence. As most architects would claim, the notion that daylight, nature and acoustics influence the experience and well-being is not considered *new* knowledge, but as the significance has become measurable and evidence-based, the relevance in the hospital context has re-gained. The decision-makers in charge of the construction of new hospitals have thus been provided with results and tools to unite knowledge on rational medical treatment with evidence-based knowledge on the design-related influence on the patients' experiences and potential healing process. The future hospitals will thus also be designed and constructed on the basis of the best knowledge available, but now with evidence-based knowledge on the design aspects as well.
With the requirements for research-based documentation in hospital design, it is reasonable to question if this project have provided sufficient knowledge to inform the decision-makers on the use of functional textiles in future hospital interiors.

Having summarised the project findings, it becomes clear that the results overall indicate that textiles can improve the patients' experience of interiors and comply with hospital hygiene, but there are still relevant issues to be researched before the practice may be changed accordingly.
As the project concerns hospital hygiene, which has a decisive and critical influence on the prevalence of hospital-acquired infections, it is essential to test and study the textiles hygiene improving properties thoroughly. In the project, the technical experimental

studies, which tested these aspects, have been conducted as pilot-studies, with the purpose to explore the possibilities of using the textiles. It would naturally have been ideal to conduct a long-term study to provide significant evidence on the technical qualities of using functional textiles, but concerned with the time frame and exploratory nature of the PhD project, the objective have been to provide pilot-study indications that covered a broader scope. Thus, even though the pilot-studies confirmed that the functional textiles could be cleaned and disinfected properly, final recommendation and implementation still awaits further studies. Long-term studies testing the bacteria levels, disinfection process and durability of the coating should therefore be conducted to consolidate the pilot-study results of this project.

From an aesthetic perspective, the findings indicate that the use of textiles in hospital interiors influence the patients' experience. The atmosphere was experienced more accommodating and home-like, when textiles were introduced as familiar and tactile dimensions of the hospital interior, and the patients even used the dayroom more, when it was refurbished at Odense University Hospital (OUH). The results from the experimental study at OUH, have raised awareness on the design qualities of using textiles for hospital interiors, but as with the technical aspects, additional studies should be conducted to consolidate the results of the aesthetic pilot-studies, and ideally link the design qualities to improved patient outcomes. In the study at OUH, the patients' use of the dayroom was increased, and if the use of interior textiles to provide accommodating hospital interiors can be linked with increased patient mobility, the potential is substantial, and these issues should be addressed in new studies.

In the project the financial concerns have not been regarded, but the use of functional textiles instead of plastic coated upholstery, will most likely cause extra costs for procurement and daily operations. However, if the use of textiles can improve the patient experiences and possibly increase patient mobility, as this project indicate, the extra costs of procurement can be realised if the patients' healing process is promoted and the patients have shorter periods of hospitalisation. As addressed in the aesthetic background studies, architectural theory and environmental psychology have related the patients' level of stress to the physical dimension of the environment. The use of textiles in hospital interiors to reduce the patients' level of stress has not been studied in this project. However, in the study at Odense University Hospital, the patients' did experienced the dayroom as more quiet, relaxing and even home-like, and it would have been interesting to combine the qualitative study on the patients' experiences with quantitative measurements of patients' stress levels, mobility, time of hospitalisation, etc. This would, however, have required a larger study, than was possible to conduct in this PhD project, but for further research studies, these issues would be very relevant to address. New research studies may thus be initiated to progress the findings of this project, and provide significant results on the design qualities of textiles in hospital interiors.

FURTHER STUDIES – A LONG-TERM INTEGRATED STUDY

Despite the findings and clear indications of this project, there are still issues to be studied before the decision-makers can decide on the use of functional textiles in future hospitals.

A solid foundation for future research projects have been established with this project that has unfolded and explored the field of functional textiles for hospital interiors, but the pilot-study results needs to be consolidated and confirmed in studies of larger scale. Decisions on hospital design have always been based on the best accessible knowledge, and significant evidence on the hygiene properties of the material and the aesthetic qualities of textiles should be further defined, before the decision makers can approve the use of functional textiles for hospitals.

In this project the design qualities were divided in a technical and aesthetic part, but to provide definitive and significant results on the qualities of using functional textiles a long-term integrated study that address both functional and aesthetic aspects would be essential to conduct.
Technical aspects of cleaning, disinfection and durability, which have also been addressed in this project, would be essential to examine in a long-term in-situ study at a Danish hospital, while at the same time studying the aesthetic aspects of the patients' design experience and the potential derived patient outcomes.

Based on the findings of this project, recommendations for a future long-term in-situ study includes:

Technical evaluations

- Continuously microbiological evaluation of the bacteria level on the textile surfaces (as performed in study B).

- Development of a new process for adequate furniture disinfection, e.g. use of SonoSteam treatments.

- Evaluation of the durability of the coating, performing repeated water-repellency tests directly on the furniture in the hospital environment (as performed in study C).

Aesthetic evaluations

- Interviews and surveys of the patients' experience in the textile-based hospital

room.

- Quantitative observations of the patients' use of the room, and qualitatively observations of the performed activities.

- Measures of the patients' stress level, blood pressure, time of hospitalisation, use of analgesics, and mobility.

- Comparison between two rooms, where the first room is kept with traditional hospital interior, and the second room is refurbished with interior textiles.

RECOMMENDATIONS FOR PRACTICE

The results of the project have not reached a level, where they yet can provide significant evidence for future implementations, but as aimed the project has explored and outlined the cross-disciplinary field of functional textiles for hospital interiors, and has provided a solid foundation for future research and development projects to progress this field further. However, this development also have implications for the practice of hospital service departments and the textile industry, and I will shortly propose some basic suggestions for these key actors.

Hospital service departments

First of all the hospital service departments, and national counsellors of hygiene and infection control, are recommended to be more proactive in the development of new interior design solutions that facilitate both hygiene concerns and the aesthetic dimensions of the patients experience. The aesthetic qualities of interior materials may be difficult to articulate and are thus often neglected in the decision-making process, but the influence on the patients' experience has been established with this project, with potential improvements related to the patients' well-being and health. Concerned with these design qualities and potentials, the hospital service departments should begin to state the demand for new types of functional textiles for hospital upholstery that can include both the technical requirements and aesthetic dimensions. There is an unexploited potential in the field of functional textiles for hospital interiors, which can improve the experience of the physical hospital environment, but the use and application of the materials will only be realised if the hospital service departments, designers and decision-makers request the use of these new materials.

The textile industry

The patients' requests for more accommodating and home-like hospital design will presumably be increased in the next couple of years, as the new hospitals will be completed, and from that perspective the textile industry could ideally influence the development of new materials to improve the patients' experience of the interior. The hygiene concerns are evidently essential, but with increased focus on the development of functional textiles with hygiene improving properties, the balance between rational and efficient cleaning ability and the emotional values and aesthetic qualities of textiles may be combined. From that perspective, the textile industry is recommended to progress the development of alternative upholstery solutions for the health care market that satisfy both the technical and aesthetic dimensions, and to be involved in future research and development projects to document the potentials and qualities of using functional textiles in hospital interiors.
This project have provided the findings and indications that can found future research projects in the field of functional textiles for hospital interiors, and here the practice are important key actors to contribute to a continuous progression.

REFERENCES

Archer, B. 1995, “The nature of research”, *Co-Design Journal,* vol. 2, no. 11.

Bang, A.L., Krogh, P.G., Ludvigsen, M. & Markussen, T. 2012, ”The Role of Hypothesis in Constructive Design Research”, Conference proceedings for: *The Art of Research 2012.* Alto University, School of Arts, Design and Architecture.

Barad, J. 2006, *Put Your Virus/Bacteria/Toxin Detecting Nanofiber Napkin Back in Your Lap!* [Online]. Available from: http://www.medgadget.com/2006/09/put_your_virusb.html. [Accessed: 10.08.2014].

Barnhart, S.K., Perkins, N.H. & Fitzsimonds, J. 1998, ”Behaviour and outdoor setting preferences at a psychiatric hospital”, *Landscape and Urban Planning,* vol. 42, no. 2, pp. 147-156.

Bate, P. & Robert, G.B. 2007, *Bringing user experience to healthcare improvement: The concepts, methods and practices of experience-based design.* Radcliffe, Oxford.

Black, S. 2007, ”Trends in smart medical textiles” in *Smart Textiles for medicine and healthcare - Materials, systems and applications*, ed. L. Langenhove. Woodhead publishing in Textiles, Cambridge, UK, pp. 3-26.

Blumberg, R. & Devlin, A.S. 2006, ”Design Issues in Hospitals The Adolescent Client”, *Environment and Behavior,* vol. 38, no. 3, pp. 293-317.

Böhme, G. 1993, ”Atmosphere as the fundamental concept of a new aesthetics”, *Thesis eleven,* vol. 36, no. 1, pp. 113-126.

Böhme, G. 1998, ”Atmosphere as an aesthetic concept” in *Daidalos ”Constructing Atmospheres”*, eds. G. Confurius, J. Bond, A. Schmedding, et al., pp. 112-115.

Böhme, G. 2013a, ”Atmosphere as Mindful Physical Presence in Space”, *Oase #91 - Building Atmosphere,* pp. 21-32.

Böhme, G. 2013b, ”The art of the stage set as a paradigm for an aesthetics of atmospheres”, *Ambiances, Rediscovering*. [Online] Available from: http://ambiances.revues.org/315 [Accessed: 08.07.2013].

Brandt, E. & Binder, T. 2007, ”Experimental design research: genealogy, intervention, argument”, Paper presented at the International Association of Societies of Design Research 2007: Emerging trends in Design, Hong Kong, China, 12.11.2007 - 15.11.2007.

Britto, M.T., DeVellis, R.F., Hornung, R.W., DeFriese, G.H., Atherton, H.D. & Slap, G.B. 2004, ”Health care preferences and priorities of adolescents with chronic illnesses”, *Pediatrics,* vol. 114, no. 5, pp. 1272-1280.

Bromley, E. 2012, ”Building patient-centeredness: Hospital design as an interpretive act”, *Social science & medicine,* vol. 75, no. 6, pp. 1057-1066.

Carpman, J.R., Grant, M.A. & Simmons, D.A. 1993, *Design that cares: Planning health facilities for patients and visitors,* Jossey-Bass.

Carr, R.F. 2011, *Hospital - Whole Building Design Guide*, National Institute of Building Sciences, [Online] Available from: www.wbdg.org. [Accessed: 07.05.2013]

Caspari, S., Naden, D. & Eriksson, K. 2007, ”Why not ask the patient? An evaluation of the aesthetic surroundings in hospitals by patients”, *Quality management in health care,* vol. 16, no. 3, pp. 280-292.

Cherenack, K. & van Pieterson, L. 2012, ”Smart textiles: challenges and opportunities”, *Journal of Applied Physics,* vol. 112, no. 9, pp. 091301.

Coad, J. & Coad, N. 2008, ”Children and young people's preference of thematic design and colour for their hospital environment”, *Journal of child health care: for professionals working with children in the hospital and community,* vol. 12, no. 1, pp. 33-48.

Cold, B. 2001, ”Introduction” in *Aesthetics, well-being and health - Essays within architecture and environmental aesthetics*, ed. B. Cold, 1st edn, Ashgate Publishing Limited, England, pp. 1-11.

Cold, B., Kolstad, A. & Larssæther, S. 1998, *Aesthetics, well-being and health: abstracts on theoretical and empirical research within environmental aesthetics,* Norsk Form.

Dalke, H., Little, J., Niemann, E., Camgoz, N., Steadman, G., Hill, S. & Stott, L. 2006, ”Colour and lighting in hospital design”, *Optics & Laser Technology,* vol. 38, no. 4, pp. 343-365.

Danish Hospital Construction 2013, *Danish Hospital Construction - Key themes of the hospital construction projects* [Homepage of Danish Regions], [Online]. Available from: http://www.danishhospitalconstruction.com/Goals-and-management/Vision%20for%20the%20regions%20hospital%20construction%20projects/Key%20themes%20of%20the%20hospital%20construction%20projects.aspx [Accessed: 14.06.2015].

Danish Patients 2009, *Fremtidens Sygehusbyggeri - Patienternes Perspektiv [Future hospital buildings - The Patients' Perspective]*, Danish Patients, [Online]. Available from: www.danskepatienter.dk. [Accessed: 07.07.2013]

Danish Standard 2009, DS/ISO 23232, *Textiles - Aqueous liquid repellency – Water/ alcohol solution resistance test*, Danish Standards.

Danish Standard 2013, *DS2451-8: Infection control in the health care sector – Requirements for laundering and handling of textiles for multiple use*, Danish Standard.

Danish Standard 2014, *DS 2451-10: Infection control in the health care sector - Part 10: Requirements for cleaning*, Danish Standard.

Danish Technological Institute 2013, *Upholstery Fabric Classification - a system for classification*, Danish Technological Institute, Taastrup, Denmark.

Daoud, W.A., Xin, J.H. & Tao, X. 2004, ”Superhydrophobic Silica Nanocomposite Coating by a Low-Temperature Process”, *Journal of the American Ceramic Society,* vol. 87, no. 9, pp. 1782-1784.

Delanty, G. & Strydom, P. 2003, *Philosophies of Social Science: The Classic and Contemporary Readings,* Maidenhead.

Denscombe, M. 2008, ”Communities of practice a research paradigm for the mixed methods approach”, *Journal of mixed methods research,* vol. 2, no. 3, pp. 270-283.

Dirckinck-Holmfeld, K., Hornung, P.M., Damgaard-Sørensen, H. & Heslet, L. 2007, *Sansernes Hospital [Hospital of the senses],* Arkitektens Forlag.

Douglas, C.H. & Douglas, M.R. 2004, ”Patient-friendly hospital environments: exploring the patients' perspective”, *Health Expectations,* vol. 7, no. 1, pp. 61-73.

Eisen, S.L., Ulrich, R.S., Shepley, M.M., Varni, J.W. & Sherman, S. 2008, ”The stress-reducing effects of art in pediatric health care: art preferences of healthy children and hospitalized children”, *Journal of child health care : for professionals working with children in the hospital and community,* vol. 12, no. 3, pp. 173-190.

Essick, G.K., McGlone, F., Dancer, C., Fabricant, D., Ragin, Y., Phillips, N., Jones, T. & Guest, S. 2010, ”Quantitative assessment of pleasant touch”, *Neuroscience & Biobehavioral Reviews,* vol. 34, no. 2, pp. 192-203.

Fijan, S., Koren, S., Cencič, A. & Šostar-Turk, S. 2007, ”Antimicrobial disinfection effect of a laundering procedure for hospital textiles against various indicator bacteria

and fungi using different substrates for simulating human excrements", *Diagnostic microbiology and infectious disease,* vol. 57, no. 3, pp. 251-257.

Fijan, S. & Turk, S.Š 2012, "Hospital textiles, are they a possible vehicle for health-care-associated infections?", *International journal of environmental research and public health,* vol. 9, no. 9, pp. 3330-3343.

FORCE Technology 2014, *Hospital mattress cover*. [Online]. Available from: http://sonosteam.dk/cms/site.aspx?p=13623 [Accessed: 28.10.2014].

Frampton, S.B., Gilpin, L. & Charmel, P.A. 2003, *Putting patients first: Designing and practicing patient-centered care,* Jossey-Bass.

Frandsen, A.K., Mullins, M., Ryhl, C., Folmer, M.B., Fich, L.B., Øien, T.B. & Sørensen, N.L. 2009, *Helende arkitektur*, Institut for Arkitektur og Medieteknologi, Aalborg Universitet, Aalborg.

Frayling, C. 1993, *Research in art and design,* Royal College of Art London.

Gadamer, H. 2008, *Philosophical hermeneutics,* Univ of California Press.

Gallace, A. & Spence, C. 2011, "Tactile aesthetics: towards a definition of its characteristics and neural correlates", *Social Semiotics,* vol. 21, no. 4, pp. 569-589.

Gallace, A. & Spence, C. 2014, *In touch with the future: The sense of touch from cognitive neuroscience to virtual reality,* Oxford University Press.

Gao, Y. & Cranston, R. 2008, "Recent advances in antimicrobial treatments of textiles", *Textile Research Journal,* vol. 78, no. 1, pp. 60-72.

Groat, L. & Wang, D. 2002, *Architectural research methods,* Wiley.

Gulrajani, M. (ed) 2013, *Advances in the dyeing and finishing of technical textiles*, Woodhead Publishing.

Hjortshøj, M. 2015, Danmark halter efter med kultur til syge [Denmark is lagging behind with culture for the sick]. *Politiken* (11.8.2015), Section 2, p. 3.

Höfer, D. 2006, "Antimicrobial textiles–evaluation of their effectiveness and safety" in *Biofunctional Textiles and the Skin*, eds. U.-. Hipler & P. Eisner, Karger Publishers, pp. 42-50.

Holm, L. 2003, "Madens betydning for patienterne", *Mad, mennesker og måltider,* pp. 279-294.

Hooper, A., Butler, P., Friend, C., Vadgama, P., Tunnicliffe, D., Hay, J. & Bowen, C. 2003, *Smart Materials for the 21st century*, Foresight Smart Materials Taskforce, London, UK, Institute of Materials, Minerals and Mining. Report no FMP/03/04/ IOM3.

Horsburgh Jr, C.R. 1995, "Healing by design", *New England Journal of Medicine,* vol. 333, no. 11, pp. 735-740.

Huang, R., Mehta, S., Weed, D. & Connie Savor Price, M. 2006, "Methicillin-Resistant Staphylococcus aureus Survival on Hospital Fomites", *Infection control and hospital epidemiology,* vol. 27, no. 11, pp. 1267-1269.

Jensen, A.A., Poulsen, P.B. & Bossi, R. 2008, *Kortlægning og miljø- og sundhedsmæssig vurdering af fluorforbindelser i imprægnerede produkter og imprægneringsmidler - Kortlægning af kemiske stoffer i forbrugerprodukter, Nr. 99 2008*, Miljøstyrelsen, Miljøministeriet.

Jensen, O.B. 2010, "Design research and knowledge - introduction to Design Research Epistemologies" in *Design research epistemologies - research in architectural design*, ed. O.B. Jensen, 1st edn, Aalborg University, Denmark, pp. 7-23.

Johnson, R.B. & Onwuegbuzie, A.J. 2004, "Mixed methods research: A research paradigm whose time has come", *Educational researcher,* vol. 33, no. 7, pp. 14-26.

Kiekens, P., Van der Burght, E., Kny, E., Uyar, T. & Milašius, R. 2014, "Functional Textiles–From Research and Development to Innovations and Industrial Uptake", *Autex Research Journal,* vol. 14, no. 4, pp. 219-225.

Kjærsig, K. & Linaa, L. 2015, *Livet mellem stuerne - Inspirationskatalog til gangarealer, vente- og opholdsmiljøer på OUH [Life between bedrooms - Inspirational catalogue for hospital wards, waiting areas and dayrooms at Odense University Hospital]*, Syddansk Sundhedsinnovation, Odense, Denmark.

Kolko, J. 2010, "Abductive thinking and sensemaking: The drivers of design synthesis", *Design Issues,* vol. 26, no. 1, pp. 15-28.

Koskinen, I., Zimmerman, J., Binder, T., Redstrom, J. & Wensveen, S. 2011, *Design research through practice: From the lab, field, and showroom,* Elsevier.

Küller, R. 1991, "Environmental assessment from a neuropsychological perspective" in *Environmental Cognition and Action. An Integrative Multidisciplinary Approach*, eds. T. Garling & G.W. Evans, 1st edn, Oxford University Press, UK, pp. 111-147.

Kvale, S. 1997, *InterView: en introduktion til det kvalitative forskningsinterview,* Hans

Reitzel.

Lang, J. 1988, ”Symbolic aesthetics in architecture: toward a research agenda” in *Environmental aesthetics Theory, Research, and Application*, ed. J.L. Nasar, 1st edn, Cambridge University Press, UK, pp. 45-55.

Lankford, M.G., Collins, S., Youngberg, L., Rooney, D.M., Warren, J.R. & Noskin, G.A. 2006, ”Assessment of materials commonly utilized in health care: implications for bacterial survival and transmission”, *American Journal of Infection Control,* vol. 34, no. 5, pp. 258-263.

Lawson, B. 2001, *The Language of Space,* Oxford, Routledge.

Lawson, B., Phiri, M. & Wells-Thorpe, J. 2003, *The Architectural Healthcare Environment and its Effects on Patient Health Outcomes*, NHS Estates. [Online]. Available from: http://www.wales.nhs.uk/sites3/documents/254/ArchHealthEnv.pdf [Accessed: 08.06.2013].

Lawson, B. 2010, ”Healing architecture”, *Arts & Health,* vol. 2, no. 2, pp. 95-108.

Leth, R.A. & Møller, J.K. 2006, ”Udviklingstendenser i forekomsten af hospitalserhvervede infektioner og antibiotikaforbrug i Århus Amt”, *Ugeskr Læger,* vol. 168, pp. 1129-1132.

Lübcke, P. (ed) 2010, *Politikens filosofileksikon*, 2nd edn, Politikens Forlag, København, Danmark.

Lund, S. 2015, *Mail correspondance: Susanne Lund, Production managaer, De Forenede Dampvaskerier [The united steam laundries]*.

Magasinet Gulv 2013*, Mikrobe-dræbende gulvbelægning* [Homepage of byggeplads.dk], [Online]. Available from: http://www.magasinetgulv.dk/nyhed/2013/01/hospital-gulvbelaegning/mikrobe-draebende-gulvbelaegning [Accessed: 20.11.2014].

Mahltig, B. & Böttcher, H. 2003, ”Modified silica sol coatings for water-repellent textiles”, *Journal of Sol-Gel Science and Technology,* vol. 27, no. 1, pp. 43-52.

Mahltig, B., Haufe, H. & Böttcher, H. 2005, ”Functionalisation of textiles by inorganic sol–gel coatings”, *Journal of Materials Chemistry,* vol. 15, no. 41, pp. 4385-4398.

Merleau-Ponty, M. 2009, *Kroppens fænomenologi,* 2. udgave edn, Helsingør, Det lille Forlag.

Miller, N.O., Friedman, S.B. & Coupey, S.M. 1998, ”Adolescent preferences for

rooming during hospitalization", *Journal of adolescent health,* vol. 23, no. 2, pp. 89-93.

Montagu, A. 1971, *Touching: The human significance of the skin.* Columbia U. Press.

Morsing, E. & Klamer, M. 2011, *Reduction of Bacteria on Textiles*, Danish Technological Institute, Wood Technology.

Mucha, H., Hofer, D., Assfalg, S. & Swerev, M. 2002, "Antimicrobial finishes and modifications", *Melliand textilberichte international textile reports,* vol. 83, no. 4, pp. 238-243.

Nanda, U., Chanaud, C.M., Brown, L., Hart, R. & Hathorn, K. 2009, "Pediatric art preferences: countering the "one-size-fits-all" approach", *Herd,* vol. 2, no. 4, pp. 46-61.

NanoPool 2015, *, NanoPool - Publications* [Homepage of NanoPool], [Online]. Available from: http://www.nanopool.eu/en/category/publications/ [Accessed: 20.07.2015].

Nasar, J. & Purcell, T. 1990, "Beauty and the beast extended: Knowledge structure and evaluations of houses by Australian architects and non-architects", in H. Pamir, V. Imamoglu, & N. Teymur (Eds.) *Culture, Space, History.* Ankara, Turkey. Sevki Vanh Foundation for Architecture.

Nickl, H. & Nickl-Weller, C. 2007, *Hospital architecture,* Braun.

Nickl-Weller, C. & Nickl, H. 2013, *Hospital architecture,* Braun.

Noskin, G.A., Bednarz, P., Suriano, T., Reiner, S. & Peterson, L.R. 2000, "Persistent contamination of fabric-covered furniture by vancomycin-resistant enterococci: implications for upholstery selection in hospitals", *American Journal of Infection Control,* vol. 28, no. 4, pp. 311-313.

Pallasmaa, J. 2013, "Atmosphere, Compassion and Embodied Experience", *Oase #91 - Building Atmosphere,* , pp. 33-53.

Pallasmaa, J. 2009, "Mental and Existential Ecology", Paper presented at the Conference OECD: Sustainable School Buildings from Concept to Reality. Organised by the Ministry of Education, Science and Sport, Slovenia, 1.-2. October 2009.

Pallasmaa, J. 2005, *The eyes of the skin: architecture and the senses,* Wiley.

Pallasmaa, J. 2001, "The Mind of the Environment" in *Aesthetics, Well-being and Health - Essays within architecture and environmental aesthetics*, ed. B. Cold,

Ashgate Publishing Limited, England, pp. 203-221.

Pan, S., Kota, A.K., Mabry, J.M. & Tuteja, A. 2012, ”Superomniphobic surfaces for effective chemical shielding”, *Journal of the American Chemical Society,* vol. 135, no. 2, pp. 578-581.

Pattison, H.M. & Robertson, C.E. 1996, ”The effect of ward design on the well-being of post-operative patients”, *Journal of advanced nursing,* vol. 23, no. 4, pp. 820-826.

Peirce, C.S. 1931-58, *Collected papers of Charles Sanders Peirce,* Harvard University Press.

Picard, D., Dacremont, C., Valentin, D. & Giboreau, A. 2003, ”Perceptual dimensions of tactile textures”, *Acta Psychologica,* vol. 114, no. 2, pp. 165-184.

Porteous, J.D. 1996, *Environmental Aesthetics: Ideas, Politics and Planning*, Routledge.

Proust, M. 1992, *In Search of Lost Time [volumes 1 to 7],* Centaur.

Purcell, A.T. & Nasar, J.L. 1995, ”Experiencing other people's houses: A model of similarities and differences in environmental experience” in *Readings in Environmental Psychology - Giving Places Meaning*, ed. L. Groat, 1st edn, Academic Press, London, pp. 201-219.

Rasmussen, S.E. 1966, *Om at opleve arkitektur,* 2nd edn, G.E.C.Gads forlag.

Rolls, E.T., O'Doherty, J., Kringelbach, M.L., Francis, S., Bowtell, R. & McGlone, F. 2003, ”Representations of pleasant and painful touch in the human orbitofrontal and cingulate cortices”, *Cerebral Cortex,* vol. 13, no. 3, pp. 308-317.

Rowlands, J. & Noble, S. 2008, ”How does the environment impact on the quality of life of advanced cancer patients? A qualitative study with implications for ward design”, *Palliative medicine,* vol. 22, no. 6, pp. 768-774.

Schindler, W.D. & Hauser, P.J. 2004, ”Repellent finishes” in *Chemical finishes of textiles*, eds. W.D. Schindler & P.J. Hauser, Woodhead Publishing Ltd, Cambridge, UK, pp. 115-133.

Shepley, M.M. 1997, "A users' guide to healthcare design research", *Journal of healthcare design*, vol. 9, pp. 9-12.

Shepley, M.M. 2006, "Evidence Based Design and Architecture" in The Architecture of Hospitals, ed. C. Wagenaar, NAi Publishers, pp. 266-270.

Stankos, M. & Schwarz, B. 2007, "Evidence-Based Design in Healthcare: A theoretical Dilemma", *Interdisciplinary Design and Research e-Journal*, vol. 1, no. 1 [Online] Available from: www.idrp.wsu.edu [Accessed 05.08.2012]

Statens Serum Institut 2014, *Nationale infektionshygiejniske retningslinjer: For desinfektion i sundhedssektoren*, Central Enhed for Infektionshygiejne, SSI. [Online]. Available from: http://www.ssi.dk/Smitteberedskab/Infektionshygiejne/Retningslinjer/NIR.aspx [Accessed. 12.08.2014].

Statens Serum Institut 2013, *Nationale Infektionshygiejniske Retningslinjer: For nybygning og renovering i sundhedssektoren*, Central Enhed for Infektionshygiejne. [Online]. Available from: http://www.ssi.dk/Smitteberedskab/Infektionshygiejne/Retningslinjer/NIR.aspx [Accessed. 12.08.2014].

Strübing, J. 2007, ”Research as pragmatic problem-solving: The pragmatist roots of empirically-grounded theorizing”, *The Sage handbook of grounded theory,* SAGE Publications Ltd. pp. 580-601.

Tao, X. 2001, ”Smart technology for textiles and clothing - introduction and overview” in *Smart fibres, fabrics and clothing*, ed. X. Tao, Woodhead publishing.

Tomšič, B., Simončič, B., Orel, B., Černe, L., Tavčer, P.F., Zorko, M., Jerman, I., Vilčnik, A. & Kovač, J. 2008, ”Sol–gel coating of cellulose fibres with antimicrobial and repellent properties”, *Journal of Sol-Gel Science and Technology,* vol. 47, no. 1, pp. 44-57.

Türk, M., Ehrmann, A. & Mahltig, B. 2014, ”Water-, oil-, and soil-repellent treatment of textiles, artificial leather, and leather”, *The Journal of The Textile Institute,* , no. ahead-of-print, pp. 1-10.

Ullán, A.M., Belver, M.H., Fernández, E., Serrano, I., Delgado, J. & Herrero, C. 2012, ”Hospital Designs for Patients of Different Ages Preferences of Hospitalized Adolescents, Nonhospitalized Adolescents, Parents, and Clinical Staff”, *Environment and Behavior,* vol. 44, no. 5, pp. 668-694.

Ulrich, C. 2006, ”Nano textiles are engineering a safer world”, *Human Ecology - Technology and Innovation; Cornell University,* vol. 34, no. 2, pp. 2-5.

Ulrich, R.S. 1984, ”View through a window may influence recovery from surgery”, *Science,* vol. 224, no. 4647, pp. 420-421.

Ulrich, R.S. 1997, "Pre symposium workshop: A theory of supportive design for healthcare facilities", Journal of Healthcare design, vol. 9, pp. 3-7.

Ulrich, R.S., Quang, X., Zimring, C., Joseph, A. & Choudhary, R. 2004, ”The role of the physical environment in the hospital of the 21st century: a once-in-a-lifetime opportunity”, Concord, USA: The Robert Wood Johnson Foundation And The Center For Health Design; 2004..

Ulrich, R.S., Zimring, C., Zhu, X., DuBose, J., Seo, H., Choi, Y., Quan, X. & Joseph, A. 2008, ”A review of the research literature on evidence-based healthcare design”, *Health Environments Research & Design Journal,* vol. 1, no. 3, pp. 61-125.

Ulrich, R.S. 1991, ”Effects of interior design on wellness: theory and recent scientific research”, *Journal of health care design,* vol. 3, pp. 97-109.

Verderber, S. 1986, ”Dimensions Of Person-Window Transactionsin the Hospital Environment”, *Environment and Behavior,* vol. 18, no. 4, pp. 450-466.

Vilcnik, A., Jerman, I., Šurca Vuk, A., Kozelj, M., Orel, B., Tomšič, B., Simoncic, B. & Kovac, J. 2009, ”Structural properties and antibacterial effects of hydrophobic and oleophobic sol− gel coatings for cotton fabrics”, *Langmuir,* vol. 25, no. 10, pp. 5869-5880.

Vindum, K. 2011, ”Komplikationer”, *Arkitekten,* vol. 113, no. 7, pp. 4.

Vindum, K., Bjerring, S., Danielsen, T., Sørensen, F., Steffensen, L. & Berner-Nielsen, W. 2011, ”Hav tillid - en rundbordssamtale med fire hospitalsarkitekter”, *Arkitekten,* vol. 113, no. 7, pp. 40.

Wagenaar, C. 2006, ”The Architecture of Hospitals” in *The architecture of hospitals*, ed. C. Wagenaar, NAi Publishers, pp. 11-19.

Walton, D. 2014, *Abductive reasoning,* University of Alabama Press.

Whitehouse, S., Varni, J.W., Seid, M., Cooper-Marcus, C., Ensberg, M.J., Jacobs, J.R. & Mehlenbeck, R.S. 2001, ”Evaluating a children's hospital garden environment: Utilization and consumer satisfaction”, *Journal of Environmental Psychology,* vol. 21, no. 3, pp. 301-314.

Yao, X., Song, Y. & Jiang, L. 2011, ”Applications of Bio-Inspired Special Wettable Surfaces”, *Advanced Materials,* vol. 23, no. 6, pp. 719-734.

Zumthor, P. 2006, *Atmospheres: architectural environments - surrounding objects,* Basel: Birkhäuser.

APPENDIX

APPENDED PAPERS

TECHNICAL PART

PAPER A

Mogensen, J, Jørgensen, P-E & Poulsen, SB 2014, 'Design Innovations and Implementation Challenges - A Case of Smart Textiles in Future Hospital Interiors'. in D Marjanović, M Štorga, N Pavković & N Bojčetić (eds), *DESIGN 2014: Proceedings of the 13th International Design Conference.* vol. 1, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia/The Design Society, Glasgow, Glasgow, s. 935-945. DESIGN, nr. 2014
[Published]

PAPER B

Mogensen, J, Jørgensen, P-E & Thomsen, TR 2015, 'A microbiological evaluation of SiO_2-coated textiles in hospital interiors: The effect of passive coatings on the cleaning potential of interior textiles' *Journal of Industrial Textiles,* s. 1-11., doi: 10.1177/1528083715580543
[Published - ePub ahead of print]

AESTHETIC PART

PAPER D

Mogensen, J, Fisker, AM & Poulsen, SB 2014, 'Interior Textiles and the Concept of Atmospheres - A Case Study on the Architectural Potential of Textiles in Danish Hospital Interiors'. in *Textile Society of America 2014 Biennial Symposium Proceedings: New Directions: Examining the Past, Creating the Future, Los Angeles, California, September 10–14, 2014. 2014 udg, 902, Textile Society of America, Los Angeles, s. 1-11.*
[Published]

PAPER E

Mogensen, J, Poulsen, SB & Hansen AG 2015, 'Interior design and healing architecture: A mixed-method study on the patients' preferences for interior textiles and textile-based furniture for future hospitals'. in Christer, K (eds) *Design 4 Health, Proceedings of the 3rd European Conference on Design4Health, Sheffield 13-16th July 2015.*
[Published]

PAPER F

Mogensen, J, Fisker, AM & Poulsen, SB 2015, 'Home-like hospital environments - How furniture and materials in a refurbished hospital dayroom influence the patient experience'. in *Journal of Interior Design.*
[In the process of 'revise and resubmit']

PAPER A

INTERNATIONAL DESIGN CONFERENCE - DESIGN 2014
Dubrovnik - Croatia, May 19 - 22, 2014.

DESIGN INNOVATIONS AND IMPLEMENTATION CHALLENGES – A CASE OF SMART TEXTILES IN FUTURE HOSPITAL INTERIORS

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Keywords: design innovation, design thinking, textiles, hospital design

1. Introduction

New products, new materials, new services and solutions are developed and introduced as new design innovations every day. Some of these innovations change the way we experience the world, and the way we plan and engage in daily activities. However, it is not all innovations that are successfully implemented, and despite they might share a great potential, they will not necessarily match contextual human values or ideals, and due to various challenges and barriers they will fail the implementation process. These challenges of innovation implementation will be the overall focus in this paper. By introducing the case of implementing smart textiles in hospital interiors, the paper relates to this design innovation and through the scope of a developed strategic framework, the implementation challenges will be discussed from an integrative design perspective. With this explorative initiative, our aim is to present specific approaches for further research to progress the design innovation and the context for implementation.

The case we will relate to in this paper is concerned with the construction of new Danish hospitals, and focuses especially on the implementation of smart textiles as new functional and hygiene improving materials, innovated on the basis of new emerging technologies.

The architecture of most current hospitals in Denmark, and the Western world, has through the last decade been widely criticised by architects and design researchers as being too clinical and institutional to fit their intended purpose of providing accommodating surroundings for modern hospital care [Wagenaar 2006], [Ulrich et al. 2008]. The architectural response to this critique, and a general societal progression towards future patient care [Gerteis et al. 1993], has led to the introduction of the design concept healing architecture, promoting a vision of improved patient recovery, supported by stimulating architecture and design [Ulrich et al. 2008], [Frandsen et al. 2009]. However, when exploring the design of the new hospitals being planned, the use of materials in the interior design of the hospital environment, seems limited to the traditional materials of vinyl, plastic and plasterboards that are also used in the current hospitals today, imparting the institutional atmosphere. From an architectural perspective, this confined material use, are considered in risk of discarding the potential of healing architecture, as it contradicts with our knowledge of the materials' general influence on the architectural experience and perception [Pallasmaa 2005], [Zumthor 2006], [Bille and Flohr Sørensen 2012].

At the same time, traditional interior textiles are being phased out in the hospital context, and are replaced by plastic or laminated textiles, with limited tactile or architecturally aesthetic qualities. These decisions, restricting the field of available materials for hospital design even further, are most often made on the basis of functional considerations and rational concerns, regarding the costs of efficient cleaning and hygiene procedures.

However, as architects and designers, we see this development, and the use of these institutional materials, as conflicting in regards to the overall vision of healing architecture, seeking to stimulate the patients' healing process through accommodating and inspiring architecture.
From this perspective, we have initiated the project "Smart Textiles in Future Hospitals", exploring how textiles in hospital interiors may have an immediate architectural potential in regards to the vision of healing architecture; and by relating to the emerging field of smart textiles, we focus on the potential balance of functional, as well as aesthetic, concerns in modern healthcare architecture.
Smart textiles are generally defined as textiles with functional properties [Tao 2001], and for hospital interiors, smart textiles are designed to provide new hygienic functionalities with antibacterial or biostatic properties [Gao and Cranston 2008]. As design innovations, these products have already been introduced to the international market [Simoncic and Tomsic 2010], and have found successful implementation in many European countries [Gao and Cranston 2008].
However, despite the potential and international success, they have not yet been implemented in a Danish context, and the benefits of the design innovations thus remain unexploited.
With this paper, we will relate to this specific issue, and from the holistic perspective of a designerly approach, we will present a strategic framework for exploring this specific implementation challenge, and provide suggestions for new approaches to the development of the design innovation of smart textiles for hospital interiors.

2. Design innovations

In order to explore the challenge of innovation implementations, and to define specific approaches to the progression of the field of smart textiles for hospital interiors, design thinking will be introduced as a holistic approach and a new design perspective to this specific area of concern.
The concept of design thinking is related to complex design problems, and defined by Tim Brown [2008] as:
"[A] discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" [Brown 2008, p. 2].
From this definition, Brown [2008] is emphasising that design thinking is first of all covering a *designerly* approach to the perception of the situation, and furthermore the transformation of the designer's methods in developing products, services, processes and even strategies. In this definition of design thinking, the fields of business, technology and human values are united, and thus establish an integrative discipline with potentially successful design innovations as the derived outcome. Relating this to the case of smart textiles in hospital interiors, this innovation may be considered as an example of successful design thinking when cogitating Western Europe as the overall context. As there through many years has been an increase of multi-resistant bacteria in European countries, the desire and motivation for finding alternatives to maintain high hygienic standards has been extensive [Møller 2011]. The development of new textiles as technological hygiene solutions has therefore been a major concern, also defining a substantial business potential, where the total production of functional textiles with antibacterial properties was estimated to 30.000 tons in Western Europe in 2000, with a predicted increase by more than 15% a year in the following years [Gao and Cranston 2008]. Thus, in a European context, the desirability and human values of the actors in modern hospitals searching for hygiene improvement; the technology feasibility; and the viable business potential, are together defining the foundation for a successful design innovation. In this case, the three fields of design thinking thus gives the possibility to unite the interdisciplinary design factors in an integrative solution, and turn technological innovation into human welfare.
However, although successful in a European perspective, the innovation of smart textiles are not yet implemented in the Danish hospital context, despite the fact that new hospitals are constructed these years, and the Danish textile industry are concerning the hospital context as an area of significant growth. As we thus consider the business potential for smart textiles stronger than ever, this paper will have concentrated focus on the link between technologies and human values. Supported by literature findings and empirical data, we will discuss how the main challenge towards implementation may be a discrepancy between the current fields of technology and human values. In the following section we

will start by introducing our overall strategic framework for this explorative analysis, eventually seeking to define new approaches to progress the innovation of smart textiles for future possible implementation success.

3. Implementation challenges

Before describing the two fields of technology and human values that in our case are considered in conflicting disharmony, we will propose a strategic framework for exploring the challenge of implementing this design innovation.

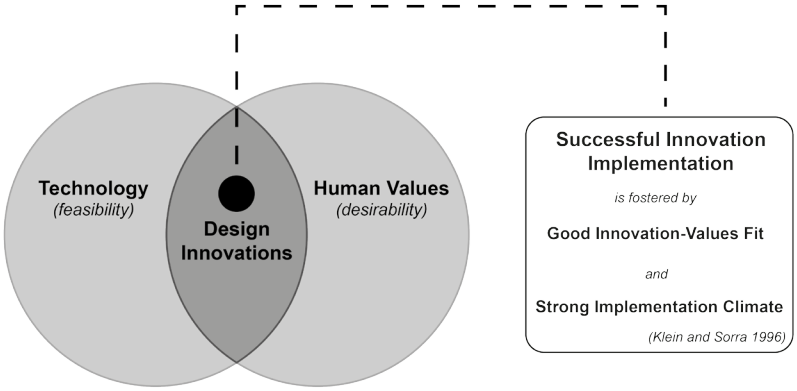

Figure 1. Model of our strategic framework for analysing design innovation implementation

As the model above illustrates, our developed strategic framework for analysing the challenge of innovation implementation, derives from the perspective of a holistic design approach. Inspired by design thinking, the fields of technology and human values are united to render a potential design innovation, and in this harmonious cross-field, Klein and Sorra's [1996] approach to successful innovation implementation is positioned; hereby proposing that the *successful innovation* implementation is a function of *a) an organisation's climate for implementation* and *b) the targeted organisational member's perception of the innovation's fit to their values* [Klein and Sorra 1996].

In our case, the technology field includes the different strategies of developing functional textiles for the hospital context, while the field of human values relates to the relevant actors defining and regulating the use of materials in hospital interiors.

According to Klein and Sorra [1996], the lack of innovation success is caused by a combination of a weak *implementation climate* and *poor innovation-values fit*, and an organisation's failure to achieve the intended benefits of an innovation, is thus reflecting either a failure of the implementation, or a failure of the innovation itself [Klein and Sorra 1996]. In the case of applying smart textiles in future Danish hospitals, we see this as an example of a design innovation with lack of implementation success. In this regard, we will explore how the fields of technology and human values may be progressed to improve the implementation climate and the innovation values-fit. The organisation may, in this case, be defined as the Danish Hospitals, where a vertical hierarchy of groups including national counsellors and regional, local hospitals are situated. In all groups *"the innovation-values fit describes the extent to which targeted users perceive that use of the innovation will foster (or, conversely, inhibit) the fulfilment of their values."* [Klein and Sorra 1996, p. 1063].

The climate for implementation are relating to the implementation policies and practices that the organisation defines for the innovation, where

"A strong implementation climate fosters innovation use by a) ensuring employee skill in innovation use, b) providing incentives for innovation use and disincentives for innovation avoidance, and c) removing obstacles to innovation use." [Klein and Sorra 1996, p. 1060]
Evidently both the innovation-values fit, and the implementation climate are essential to consider when proposing innovations for any large organisation, and initiatives regarding these concerns, will potentially bring the fields of technologies and the human values closer together. Having presented this overall strategic framework for exploring the implementation challenges, we will in the next two sections give an overview of the two fields of technology and human values, before discussing the challenges of implementation from the specific case perspective.

4. Smart textiles – technologies

In this first of two overview sections, we will introduce the technology of smart textiles with a short review of the different technologies and strategies currently available in the European market. Today the risks of hospital-acquired infections (HAI) in Danish hospitals are high, and studies have shown that app. 10% of all patients are infected during hospitalisation [Leth and Møller 2006], [Jensen 2007]. Traditional textiles have in that regard long been known as potential bacteria reservoirs [Gao and Cranston 2008], and bacterial survival on textile surfaces has been measured to several weeks in a range of studies [Noskin et al. 2000], [Neely and Maley 2000], [Lankford et al. 2006], [Huang et al. 2006]. However, by introducing smart textiles in hospital interiors, new technologies can provide the textiles with specially designed functional properties improving the general hygiene level and the possibilities of using textiles. The technological treatments of textiles may coarsely be divided in two categories; the *active* and the *passive* technologies [Mucha et al. 2002], [Höfer 2006], where the active technologies, traditionally, has been the primary solution in a European context. In order to analyse the link between technologies and human values, we will in this chapter give a short overview of the different strategies and technologies to obtain an antibacterial or biostatic textile.

4.1 Active technologies

The *active technologies* are based on *synthetic organic compounds*, *metallic compounds,* or *natural organic compounds*, consisting of antimicrobial substances or metallic ions that affects the cell membrane, the metabolism, or the core substance of the microorganism. This prevents cell division, and the bacteria will be decomposed. The effectiveness of textiles with active antibacterial properties is depending on the diffusion of the bioactive substance or the metal ions to the textile surface [Mucha et al. 2002], [Höfer 2006], [Gao and Cranston 2008].

4.1.1 Synthetic organic compounds

Based on *synthetic organic compounds* the antibacterial agent Triclosan has been used since the 1960s as a broad-spectrum and effective substance also applied and used in several textile finishing [Gao and Cranston 2008]. As Triclosan later has been found to promote bacteria resistance [Yazdankhah et al. 2006], its "unnecessary use" is today cautioned against in most European countries [Gao and Cranston 2008]. In the same category of synthetic organic compound, another alternative of using QAC (Quaternary Ammonium Compounds) is available as a widespread antibacterial agent for textile finishing. Through covalent bonds to the textile material the product adherence is good and allows for several wash cycles. Resistance is widely observed and related to some types of QAC, although little information, on the single type that are most applied in textile finishing today, are available [Gao and Cranston 2008], [Simoncic and Tomsic 2010]. Besides Triclosan and QAC, other synthetic organic compounds may be used for textile finishing, as for instance PHMB and N-Halamine [Gao and Cranston 2008].

4.1.2 Metallic compounds

In the field of strategies based on *metallic compounds* it is products with *silver* that have had the strongest growth rate in a European context. The silver may be applied as a finishing or be incorporated in the polymer fibres for increased durability. In both cases the silver diffuses and forms

the antibacterial Ag^+ ions in contact with moisture, which are particularly efficient to most microorganisms. However, silver are found being in high risk of increasing bacteria resistance, and its environmental impact are furthermore of certain ecotoxicity risks [Gao and Cranston 2008], [Wijnhoven et al. 2009], [Marambio-Jones and Hoek 2010], [Hansen and Baun 2012]. Other metals may also be used for antibacterial impacts, including cobber and zinc compounds, among others [Dastjerdi and Montazer 2010].

4.1.3 Natural organic compounds

Finally the *natural organic compounds,* as for instance *chitosan,* are to be mentioned within the group of active technologies. Extracted from crustacean's outer shell, it has a natural antibacterial effect, and is even completely biodegradable and biocompatible. Despite great potentials, disadvantages of the handle of the fabric, among other factors, has caused that chitosan until know only have found limited application in textile finishing [Lim and Hudson 2003], [Gao and Cranston 2008], [Simoncic and Tomsic 2010].

4.2 Passive technologies

The other category of textile finishing that we will include in this overview, is defined as *passive technologies*. Based on biostatic compounds they provide easy-to-clean surfaces, and with no bioactive effects the bacteria cells are not directly affected. Instead the structure of the fibre and the surface of the textile are manipulated in order to prevent the bacteria from adhering to the fibre surface, thus hampering the bacteria growth conditions [Mucha et al. 2002], [Höfer 2006].

4.2.1 Nano structured surfaces

The category of passive technologies includes products with *nano-structured surfaces* exploiting for instance the lotus effect, where the rough and super-hydrophobic surface of the textile inhibits bacteria adherence and makes the surface easy to clean. This effect may be achieved with a physical nano-structured surface combined with various compounds [Solga et al. 2007]. Textiles based on this technology are recently introduced to the market, where its potential has received great interest and attention [Sawhney et al. 2008].

4.2.2 Textile finishing

Alternatively, passive textile finishing as for instance fluorocarbon compounds can be applied as an efficient water repellent product. Nevertheless, the use of PFOA, and earlier PFOS, in the manufacturing of fluoropolymers as for instance Teflon, has raised a range of environmental issues with some of these products. New standards have however these years been adopted by manufacturers, enabling the use of alike products in the future [Jensen et al. 2008].
A final strategy in the category of passive technologies to be mentioned in this paper is the use of *silicon dioxide*. Based on the principles of the wet-chemical sol-gel process, SiO_2 molecules are bonded to the textile surface, providing an ultra-thin transparent layer without changing the textile handle. The technology provides easy-to-clean surfaces, and being biocompatible their environmental potential seems remarkable, although only few studies on ecotoxicity exists [Jindasuwan et al. 2009], [Connor 2010], [Mikkelsen et al. 2011], [Latthe et al. 2012].

Smart Textile Technologies for Hospital Environments

Active Technologies	Passive Technologies
■ Synthetic Organic Compounds *Triclosan, QAC, PHMB, N-Halamine, etc.* ■ Metallic Compounds *Silver, Cobber, Zinc, etc.* ■ Natural Organic Compcunds *Chitosan, Milk fibres, etc.*	■ Nano Structured Surfaces *Physically re-structured surfaces, Lotus effects, etc.* ■ Textile Finishing *Fluorocarbon compounds, Teflon, Silicon dioxide, etc.*
■ *Actively kills the bacteria on contact with the active surface.* ■ *Main issues with risk of increased bacteria resistance.*	■ *Biostatic, easy-to-clean, surface inhibiting bacteria growth.* ■ *Issues of bacteria resistance are generally avoided.*

Figure 2. Overview of the technologies for smart textiles in hospital interior environments

4.3 Strategies - technologies for the hospital context

With this overview of the different available technologies, it has been our intention to present the two overall strategies of *active* or *passive* technologies within the field of smart textiles that are immediate applicable for the hospital context. Today, the passive technologies are rarely used, while the active is used more widely in European countries. Nevertheless, the active technologies, having issues regarding bacteria resistance, are in some countries attracting a considerable concern, which results in barriers towards direct implementation. In the following section, this concern will be unfolded within a Danish context, relating to the human values of the organisation of Danish hospitals as users of the design innovation.

5. Smart textiles – human values

As defined earlier, the human values of the organisation should be linked to the technology to ensure the foundation for successful implementation. In this section will relate to the Danish hospitals as the overall organisation, and elaborate on how this organisation relate to the proposed innovations of smart textiles for hospital interiors. The hospital organisation as a whole is evidently broad and covering a complex field of disciplines. However, concerning the decision on the use of materials in hospital interiors, it is first and foremost related to the hospital infection control to recommend the use of smart textiles as new innovations.

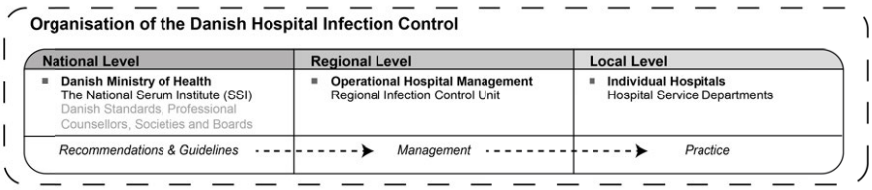

Figure 3. Simplified diagram of the Danish organisation of hospital infection control. Based on work by Riisberg [2011a]

5.1 Organisation of hospital infection control

The national organisation of hospital infection control are organised in a consulting hierarchy, where the *national* counsellors under the Danish Health and Medicines Authority are ranked highest in the organisation proposing *guidelines and recommendations* to the *regional* hygiene teams and the service departments at the *local* hospitals. While introducing these three levels of the national, regional and local organisation, we will elaborate on their ideals and standards towards the use of smart textiles in hospital interiors. This description is based on explorative empirical data collected through meetings with actors in the field of Danish hospitals and the textile industry, and matched with literature and findings by Vibeke Riisberg [2011b] in the Danish project "Textiles in Future Hospitals - User-driven innovation and communication of textiles qualities".

Regarding the application of smart textiles for hospital interiors, it is above all the Danish Ministry of Health and the Danish Health and Medicines Authority that on the *national level* are the supreme authorities on the national health issues. Under the Ministry of Health, The National Serum Institute (Statens Serum Institut - SSI) is organized as a public enterprise, with the main task of securing preparedness towards infectious disease. Being the national laboratory of microbiology, they together with other national organisations, support the development of national guidelines and instructions on hospital hygiene and infection control, as well as recommend strategies and products for disinfection in the health care sector [SSI 2013]. They are accordingly considered the main leading actor on the national level, and their recommendations are the foundation for infection control of regional and local hospitals in Denmark. The approach and authorisation of SSI is not to legislate or regulate against the use of certain materials, and their concern is instead formulated as recommendations and guidelines. Nevertheless these recommendations are followed accordingly, and in the quarterly newsletter from the Central Unit on Infection Control (Central Enhed for Infektionshygiejne – CEI), SSI respond to a

range of enquiries on the use of silver based products, including textiles, in the Danish health care sector. The immediate conclusion is clear, and due to the risk of resistance and uncertain effect on the human normal flora, the use of silver based products cannot be recommended [Jensen 2007]. There are naturally other groups relating to the national level of infection control, including Danish Standards, who develops and provides standards on hospital cleaning, as well as a range of counselling organisations, societies and boards, however usually sharing the immediate outline presented by SSI (for further information and a more thorough description see [Riisberg 2011a]).
In Denmark the operational management of the hospitals are situated at *regional level.* Here, the regional infection control unit are organised with a hospital team, where hygiene nurses supervise across local hospitals and takes precautionary measures against hospital-acquired infections [Riisberg 2011a]. On the *local level,* it is most often the service departments at the individual hospitals who are maintaining the physical environment of the hospital by undertaking the daily cleaning as well as purchasing of new interior objects. As a defined standard, the actors on the *local level* consult with the *regional* infection control team, and the regional purchasing department, regarding the choice of new textile based interior objects, like furniture, curtains, etc. Together, they base their guidance on the recommendations of SSI at *national level* [Riisberg 2011a], generally emphasising that before using antibacterial products in Danish hospitals there should be evidence that they are working - without any unnecessary risk.
However, as this position towards active technologies only is formulated as a recommendation, products based on these technologies, are still being attempted introduced on local levels by companies within the textile or building industry. However, as the general position by SSI is observed on regional and local level, the human values of the organisation of infection control are considered shared. From this perspective the statement is clear, and as the use of smart textiles with active technologies concerns a risk of increased resistance, these products are currently not recommended in Danish hospitals, and their potential use are thus strictly limited. However, the passive technologies, exploiting the biostatic properties of easy-to-clean textile surfaces, are fundamentally relating on another strategy, which may be more in line with the human values and principles of the key actors in the organisation.

6. Discussion – new approaches to the implementation challenges

Having presented this short overview of the fields of technologies and human values, we will argue that the unsuccessful national implementation is related to an inadequate link of these fields; with a poor innovation-values fit and a weak implementation climate as direct consequences. According to Klein and Sorra [1996], this combination of innovation-values fit and implementation climate is resulting in *"essentially no innovation use"* [Klein and Sorra 1996, p. 1066] and browsing through the context of Danish hospitals this is illustrated as the general case. As the architectural potential of textiles in hospital interiors, relating to the vision of healing architecture, still is unexploited in a Danish context, new approaches are considered needed to facilitate the implementation of smart textiles as new design innovations. Relating to the concept of design thinking, and our strategic framework, these new approaches should support the connection of the fields of technology and human values. This we suggest could be achieved through progressions related to the framework and the model by Klein and Sorra [1996]. This first of all calls for improvement of the innovation-values fit, and an increased focus on the technology, or innovation, itself. Currently, the focus on active technologies will potentially increase the risk of resistance, which is in strong discrepancy to the values and ideals of the Danish organisational actors. Although the current active technologies certainly have their potential and relevance in many contexts, we, from a national perspective, sees an immediate stronger potential in increasing the focus on developing the passive technologies. This would also relate to the current practice and system of hygiene control and cleaning at Danish hospitals, and is thus more likely to improve the potential implementation success.
Concerning the implementation climate, Klein and Sorra [1996] are regarding three aspects that foster a strong innovation climate, including a) ensuring skills in innovation use; b) providing incentives for innovation use, and c) removing obstacles for innovation use [Klein and Sorra 1996]. While this naturally calls for internally organisational changes, we from an external perspective, sees a strong

need for disseminating new research based knowledge to the users in the hospital organisation, regarding the specific smart textile products and their architectural potential in hospital interiors.
With these specific initiatives, searching to overlap the fields of technology and human values, our paper defines a call for further research improving the innovation-values fit by *progressing the innovation, or technology, itself*, and to improve the implementation climate by *providing the users' with knowledge on the architectural potential and qualities of textiles in hospital interiors*. With these new case specific suggestions, regarding changes in the fields of both technology and human values, we hope to support the progression of the design innovations for a future successful implementation.

7. Conclusion

Having presented the case of smart textiles for hospital interiors as a promising innovation, however unsuccessful in a Danish context, we have explored how a strategic framework departing from the holistic concept of design thinking, could act as a model for analysing these challenges of innovation implementations. The link between technologies and human values was defined as a main concern in our case, and through an explorative analysis a discrepancy in the primary active technologies and the human values of the Danish infection control organisation was defined. In this paper, the business field was not included in the analysis, although equally important in regards to the holistic approach in strategic design thinking. This study, of viable and commercial business aspects, thus remains as an interesting field for further research, linking the physical environment and the patient experience to economic potentials of possible shorter hospital stays. Nevertheless, with our focus on the technology and the human values, we have contributed with the development of an overall strategic framework that has acted as a functional tool and model to analyse the challenges of innovation implementation. Furthermore, based on this framework, we have defined a strong need for new initiatives to progress the innovation, or the technology, itself and to increase the knowledge on smart textiles and their architectural qualities and potentials.
Design thinking has gained ground in the design field as a holistic and integrative approach to developing successful design innovations. In this paper, we have build on this integrative concept of understanding design innovations, and have found it useful as foundation for a strategic framework for exploring the challenges of implementation. Although developed with this particular case in mind, the framework is also considered applicable in other areas, where a similar designerly and integrated holistic perspective, could promote other research or industrial R&D projects, where the innovation implementation may be a challenge.
Concerning our case, the hospital organisation shares a strong focus on the rational and functional concerns regarding the materials in the hospital environment. However, the easy hygienic solution providing future hospitals with smooth and hard surfaces of plastic and vinyl, are considerably in high risk of providing even more clinical and institutional hospitals as experienced and criticised today. Thus the potential of implementing smart textiles in future hospitals are believed to be widely comprehensive, in terms of both functional and aesthetic aspects, but as illustrated through our explorative analysis, the potential will remain unexploited if not a more holistic and progressive approach to the design innovation is established. Through this paper, we have suggested the following new approaches regarding the fields of technologies and human values respectively: 1) Increase the focus on passive, or alternative active, technologies to meet the stated values of the hospital organisation. 2) Increase the knowledge on the architectural qualities of textiles, and their influence on the atmosphere of the hospital environment. Having suggested these specific implications, from the basis of this paper, we will continue our work to define the architectural demand for these new materials, and thus hope to strengthen the incentive and climate for future implementation. As the research on new strategies and technologies are constantly on going, and some passive technologies are already available, we as architects and designers will direct the users in the hospital context. Hence, concerned with the patients' experience of the physical hospital environment, this work will be continued in our project "Smart Textiles in Future Hospitals", and will be conducted on the basis of a range of design experiments, planned to be carried out at Danish hospitals in the following phase of the project.

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References

Bille, M., Flohr Sørensen, T., "Materialitet: en indføring i kultur, identitet og teknologi", Frederiksberg, Samfundslitteratur, 2012.

Brown, T., "Change by design", HarperCollins, 2009.

Brown, T., "Design thinking", Harvard business review, 86, 2008, p. 84.

Connor, S., "The miracle spray-on glass that stops the bugs", The Independent, 8/9, 2010.

Dastjerdi, R., Montazer, M., "A review on the application of inorganic nano-structured materials in the modification of textiles: focus on anti-microbial properties", Colloids and Surfaces B: Biointerfaces, 79, 2010, pp. 5-18.

Frandsen, A. K., Mullins, M., Ryhl, C., Folmer, M. B., Fich, L. B., Øien, T. B. , Sørensen, N. L., "Helende arkitektur", Institut for Arkitektur og Medieteknologi, Aalborg Universitet, 2009.

Gao, Y., Cranston, R., "Recent advances in antimicrobial treatments of textiles", Textile Research Journal, 78, 2008, pp. 60-72.

Gerteis, M., Edgman-Levitan, S., Deleay, J.,Delbanco, T. L., "Introduction: medicine and health from the patient's perspective", Gerteis, ME-L., S./Deleay, J./Delbanco, TL (Hg.): Through the Patient's Eyes.Understanding and Promoting Patient-Centered Care. San Francisco: Jossey-Bass Publishers, 1993, pp. 1-5.

Hansen, S. F., Baun, A., "When enough is enough", Nature Nanotechnology, 2012.

Höfer, D. "Antimicrobial textiles–evaluation of their effectiveness and safety" in Biofunctional Textiles and the Skin, eds. U.-C. Hipler and P. Eisner, Karger Publishers, 2006, pp. 42-50.

Huang, R., Mehta, S., Weed, D., Price, M. C. S., "Methicillin-Resistant Staphylococcus aureus Survival on Hospital Fomites", Infection control and hospital epidemiology, 27, 2006, pp. 1267-1269.

Jensen, A. A., Poulsen, P. B., Bossi, R., "Kortlægning og miljø- og sundhedsmæssig vurdering af fluorforbindelser i imprægnerede produkter og imprægneringsmidler - Kortlægning af kemiske stoffer i forbrugerprodukter, Nr. 99 2008", Miljøstyrelsen, Miljøministeriet, 2008.

Jensen, E. T., "States Serum Institut: CAS-Nyt nr. 105, oktober 2007", ed., Statens Serum Institut, 2007.

Jindasuwan, S., Nimittrakoolchai, O., Sujaridworakun, P., Jinawath, S., Supothina, S., "Surface characteristics of water-repellent polyelectrolyte multilayer films containing various silica contents", Thin Solid Films, 517, 2009, pp. 5001-5005.

Klein, K. J., Sorra, J. S., "The challenge of innovation implementation", Academy of management review, 21, 1996, pp. 1055-1080.

Lankford, M. G., Collins, S., Youngberg, L., Rooney, D. M., Warren, J. R., Noskin, G. A., "Assessment of materials commonly utilized in health care: implications for bacterial survival and transmission", American Journal of Infection Control, 34, 2006, pp. 258-263.

Latthe, S. S., Gurav, A. B., Maruti, C. S., Vhatkar, R. S., "Recent progress in preparation of superhydrophobic surfaces: a review", Journal of Surface Engineered Materials and Advanced Technology, 2, 2012, pp. 76-94.

Leth, R. A., Møller, J. K., "Udviklingstendenser i forekomsten af hospitalserhvervede infektioner og antibiotikaforbrug i Århus Amt", Ugeskr Læger, 168, 2006, pp. 1129-1132.

Lim, S., Hudson, S. M., "Review of chitosan and its derivatives as antimicrobial agents and their uses as textile chemicals", Journal of Macromolecular Science, Part C: Polymer Reviews, 43, 2003, pp. 223-269.

Marambio-Jones, C., Hoek, E. M., "A review of the antibacterial effects of silver nanomaterials and potential implications for human health and the environment", Journal of Nanoparticle Research, 12, 2010, pp. 1531-1551.

Mikkelsen, S. H., Hansen, E., Christensen, T. B., Baun, A., Hansen, S. F., Binderup, M., "Survey on basic knowledge about exposure and potential environmental and health risks for selected nanomaterials", Danish Ministry of the Environment, Environmental Protection Agency, 2011.

Møller, J. K., "Bekæmpelse af resistente hospitalsbakterier - mindre antibiotika og mere infektionsforebyggelse", Ugeskr Læger, 173(37), 2011, pp. 2264-2266.

Mucha, H., Hofer, D., Assfalg, S.,Swerev, M., "Antimicrobial finishes and modifications", Melliand textilberichte international textile reports, 83, 2002, pp. 238-243.

Neely, A. N., Maley, M. P., "Survival of enterococci and staphylococci on hospital fabrics and plastic", Journal of clinical microbiology, 38, 2000, pp. 724-726.

Noskin, G. A., Bednarz, P., Suriano, T., Reiner, S., Peterson, L. R., "Persistent contamination of fabric-covered furniture by vancomycin-resistant enterococci: implications for upholstery selection in hospitals", American Journal of Infection Control, 28, 2000, pp. 311-313.

Pallasmaa, J., "The eyes of the skin: architecture and the senses", Wiley, 2005.

Riisberg, V., "Arbejdsnotat Hygiejne - Brugerdreven Innovation og Kommunikation af tekstile kvaliteter", Kolding Designskole, 2011a.

Riisberg, V., "Arbejdsnotat Research & Workshop - Tekstiler på Fremtidens Sygehuse", Kolding Designskole, 2011b.

Sawhney, A., Condon, B., Singh, K., Pang, S., Li, G., Hui, D., "Modern applications of nanotechnology in textiles", Textile Research Journal, 78, 2008, pp. 731-739.

Simoncic, B., Tomsic, B., "Structures of novel antimicrobial agents for textiles-a review", Textile Research Journal, 80, 2010, pp. 1721-1737.

Solga, A., Cerman, Z., Striffler, B. F., Spaeth, M., Barthlott, W., "The dream of staying clean: Lotus and biomimetic surfaces", Bioinspiration & biomimetics, 2, 2007, p. S126.

SSI, "About SSI - Statens Serum Institut", Available: <http://www.ssi.dk/English/Service/AboutSSI.aspx> [2013, 11/26], 2013.

Tao, X., "Smart technology for textiles and clothing - introduction and overview" in Smart fibres, fabrics and clothing, ed. X. Tao, Woodhead publishing, 2001.

Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H., Choi, Y., Quan, X., Joseph, A., "A review of the research literature on evidence-based healthcare design", Health Environments Research & Design Journal, 1, 2008, pp. 61-125.

Wagenaar, C., "The Architecture of Hospitals", in The architecture of hospitals, ed. C. Wagenaar, NAi Publishers, 2006, pp. 11-19.

Wijnhoven, S. W., Peijnenburg, W. J., Herberts, C. A., Hagens, W. I., Oomen, A. G., Heugens, E. H., Roszek, B., Bisschops, J., Gosens, I., Van De Meent, D., "Nano-silver-a review of available data and knowledge gaps in human and environmental risk assessment", Nanotoxicology, 3, 2009, pp. 109-138.

Yazdankhah, S. P., Scheie, A. A., Høiby, E. A., Lunestad, B., Heir, E., Fotland, T. Ø, Naterstad, K., Kruse, H., "Triclosan and antimicrobial resistance in bacteria: an overview", Microbial Drug Resistance, 12, 2006, pp. 83-90.

Zumthor, P., "Atmospheres : architectural environments - surroundins objects", Basel, Birkhäuser, 2006.

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PAPER B

Article

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A microbiological evaluation of SiO_2-coated textiles in hospital interiors: The effect of passive coatings on the cleaning potential of interior textiles

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Abstract

The use of passive coatings could be a new solution to improve the cleaning potential of interior textiles in hospitals. In these years, the scepticism toward the use of antibacterial textiles in the health care sector is emerging, and in the Nordic countries, the implementation success is confined. From this perspective, the purpose of this paper is therefore to address focus on alternative passive coatings that without actively killing the bacteria provide a hydrophobic and easy-to-clean textile surface. The paper relates to an in-situ study evaluating the effect and cleaning potential of SiO_2-coated textiles compared to traditional textiles and a hard plastic surface as a reference material. Through the study, arranged at an outpatient lung department at Hospital Vendsyssel, Denmark, five different surface materials were installed on hospital chair armrests and sampled with microbiological contact plates through a three-week period. By determining the level of contamination on these surfaces, the study illustrates that the SiO_2-coated textile is possible to clean to an acceptable level below the critical limit value of 2,5 Colony Forming Units (CFU) per cm^2. In comparison, the traditional textiles were only cleaned to the

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acceptable level in 56% of the microbiological controls, while the regular hard plastic surface only had acceptable levels of contamination in 25% of the samplings.

Keywords
Coated textiles, materials performance, hospitals, microbiological evaluation, cleaning potential

Introduction

Traditional textiles have long been known as a potential bacteria reservoir increasing the risk of spreading nosocomial infections [1–5]. As a response to this hygiene risk of using traditional textiles, an increased emergence of antibacterial textiles has been introduced to the health care market in recent years [6]. In a range of in vitro studies, these antibacterial textiles have proven their efficiency in reducing and eliminating bacteria growth [7–9], and in situ studies have also shown an, although less significant, effect in the real-life hospital context [10, 11].

The market penetration of these antibacterial textiles has in a period of years been extensive in both the health care sector and in a range of consumer products [1], but in these years, an increased scepticism toward these antibacterial textiles has developed in the Nordic countries [12–14] especially concerning the lack of knowledge on the potential increase of bacterial resistance and potential environmental issues [15–17]. As a consequence, Denmark, as one of the specific countries, has currently no desire in using antibacterial textiles in the health care sector [13].

Instead, interior textiles in hospitals are replaced by plastic-coated upholstery that may increase the cleaning potential, but not without confining the patient comfort, and challenging the architectural visions of an accommodating and supporting physical environment [18].

New materials and technologies, however, already exist, and based on alternative passive strategies, the interior textiles can be coated with a hydrophobic and easy-to-clean surface [14]. Based on these passive strategies, the bacteria are not affected actively or killed, and will therefore not directly induce the risk of increased bacterial resistance [14].

Coated textiles, containing hydrophobic properties, have in recent years received increased commercial interest, and focus has been directed toward the development of more environmental friendly and durable coatings [19]. However, despite the use of these passive coatings in the field of apparel, or even on hard surfaces in the food industry [20], the experience in the hospital context is rather limited [21]. To broaden the field on the application of these passive, nonantibacterial textile coatings in the health care market, this paper will specifically explore if a coating of SiO_2 can provide a textile surface with an improved cleaning ability.

In regard to the environmental awareness in the hospital context, the SiO_2 coating is considered a suitable solution, as this fundamentally is based on a fluorocarbon-free technology. The coated textiles are generally designed to prevent fluid

permeation and to restrict bacterial growth [22], and they will potentially contribute to a more cleaning-friendly hospital interior. The specific effect of the cleaning potential was investigated in an in situ study at a Danish hospital. Aiming to evaluate the effect of nonantibacterial SiO_2-coated textiles in hospital interiors, focus in this study is directed toward hospital upholsteries as they are considered to constitute the critical challenge in regard to cross-contamination and nosocomial infections.

Methods

Premises

As the purpose of this study is to conduct an in situ test on the cleaning potential of SiO_2-coated textiles in hospital interiors, the specific premises for the study should be in continuous use during the day to increase the necessity for cleaning. Therefore, a demarcated waiting room at the outpatient lung department, Sygehus Vendsyssel (Hospital Vendsyssel), Hjørring, Denmark, was settled as the specific context. To represent the ''worse-case-scenario'' of upholsteries, the different textiles were installed on the armrest of existing hospital chairs (Figure 1). Here the patients' hands are in direct contact with the chairs, which constitute the greatest risk of cross-contamination. The specific premises offered a broad patient mix

Figure 1. Illustration of the armrest where five different surfaces were installed during the test study.

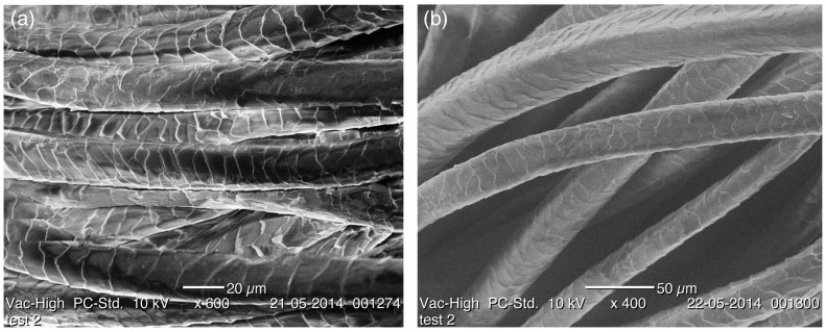

Figure 2. SEM images of WO fibres: (a) noncoated standard WO fibre and (b) WO fibre coated with SiO_2.

and an ongoing flow of patients, and this constant people traffic was important to have all the different chairs frequently in use.

Materials

Materials for the test included a Trevira CS polyester-based (PES) and a WO-based (WO) textile, Gabriel Step Trevira CS, and Gabriel Gaja Classic, respectively. Designed for upholsteries, both fabrics had similar weight (336–378 g/m^2) and being plain weaved the textile design defined the same surface structure.

Nobicon A/S, Danish distributor of the NanoPool GmbH "liquid glass coating," performed the water-based SiO_2 coating that contains SiO_2 molecules as the functional ingredient. The solution is sprayed on the textile surface and is allowed to dry for 24 h at 20°C. As illustrated in the Figure 2, the coating is active at fibre level, and in low concentration (2–10% of SiO_2), the solgel-processed coating forms an 80 - to 100-nm thin glass membrane at the surface of the textile fibres. This passive coating of SiO_2 performs hydrophobic and defines an easy-to-clean surface that prevents bacteria growth [23–25]. Contact angles are determined for water droplets as $135 \pm 4°$ for the coated WO fabric, and $128 \pm 4°$ for the coated PES. Despite the hydrophobic properties, the textile handling is maintained in full, and there is no visual or tactile difference in the coated versus noncoated textile surface.

For the study, five different material surfaces were defined: the PES textile in a coated and noncoated version; the WO textile in a coated and noncoated version; and a regular plastic armrest, as a hard-surfaced reference material (Table 1).

Surface sampling and cleaning procedure

In the in situ study, the bacterial contamination of the various material surfaces is naturally not controlled, and to evaluate the cleaning potential, the surfaces were sampled *before cleaning* and *after cleaning* to determine the bacteria reduction.

Table 1. Overview of the five different surfaces tested.

Mat. ID	Name	Fibre	Coating
1	Gabriel Step Trevira CS	Polyester (PES)—*Trevira CS*	Noncoated
2	Gabriel Step Trevira CS	Polyester (PES)—*Trevira CS*	SiO_2 (NanoPool GmbH)
3	Gabriel Gaja Classic	Wool (WO)—*New Zealand wool*	Noncoated
4	Gabriel Gaja Classic	Wool (WO)—*New Zealand wool*	SiO_2 (NanoPool GmbH)
5	Regular armrest	Hard surface—*Plastic*	Noncoated

Cleaning the armrests was performed according to current hospital practice, using the currently valid cleaning procedure defined by the required national guidelines and standard ''Infection control in the health care sector—part 10 requirements for cleaning'' [26]. The surface was thus cleaned by damp wiping with a clean cloth and clean water containing a cleaning agent, with mechanical rubbing of the surface [26]. Following this cleaning process, the surfaces were allowed to dry for 20 min before resampling the surface for the *after cleaning* control. During this time frame, the chairs and the waiting room were not in use.

Through the test study, surface samples were collected after 24 h, 48 h, one week, and three weeks after installation of the textiles in the waiting room.

Microbiology

TTC Total Count Dipslides (Transia GmbH) were used for the surface sampling. As the potential risk of nosocomial infections transmitted through surface materials is related to the contact between patient and surface, dipslides with contact agar plates were found suitable for the microbiological sampling. The dipslides were flexible at the base and granted a firm and evenly pressure against the surface being sampled. The dipslides had two independent sides (side A and side B). Both sides contained culture media for total count of microbial presence, and to expand the specific sample area of each tested surface, sides A and B were pressed against the surface on two different places. For each surface, two microbiological samples (side A and side B) were thus collected, and both samples are presented in the results (Table 2). Immediately after the sampling, the dipslides were placed in the original container, and the lid was closed tightly and stored in a lightproof container for transportation. Prior to incubation, the lid was opened, and the dipslides were incubated in aerobic conditions at 35°C for 72 h, according to manufacturer's recommendation. The microbial growth was quantified as <2.5 CFU/cm^2 = scanty contamination (S); 2.5–5.0 CFU/cm^2 = light contamination (L); 5–15 CFU/cm^2 = moderate contamination (M); and >15 CFU/cm^2 = heavy contamination (H), inspired by the manufacturer's instruction (see Figure 3 for illustration).

This categorization enabled the results to be analyzed according to the present standards for microbiological control and evaluation of cleanliness on hospital

Table 2. Results from surface sampling on five different armrest surfaces.

		24 h		48 h		One week		Three weeks	
Armrest surface	Side	Before cleaning	After cleaning	Before cleaning	After cleaning	Before cleaning	After cleaning	Before cleaning	After cleaning
1. PES *Traditional*	A	Heavy cont. *(H)*	Light cont. *(L)*	Light cont. *(L)*	Light cont. *(L)*	Moderate cont. *(M)*	Scanty cont. *(S)*	Light cont. *(L)*	Scanty cont. *(S)*
	B	Heavy cont. *(H)*	Light cont. *(L)*	Moderate cont. *(M)*	Scanty cont. *(S)*	Moderate cont. *(M)*	Light cont. *(L)*	Light cont. *(L)*	Scanty cont. *(S)*
2. PES + SiO_2	A	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Moderate cont. *(M)*	Scanty cont. *(S)*
	B	Light cont. *(L)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Moderate cont. *(M)*	Scanty cont. *(S)*
3. WO *Traditional*	A	Heavy cont. *(H)*	Light cont. *(L)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Moderate cont. *(M)*	Light cont. *(L)*	Scanty cont. *(S)*	Scanty cont. *(S)*
	B	Heavy cont. *(H)*	Light cont. *(L)*	Light cont. *(L)*	Scanty cont. *(S)*	Moderate cont. *(M)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*
4. Wool + SiO_2	A	Scanty cont. *(S)*	Scanty cont. *(S)*	Light cont. *(L)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Heavy cont. *(H)*	Scanty cont. *(S)*
	B	Light cont. *(L)*	Scanty cont. *(S)*	Light cont. *(L)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Scanty cont. *(S)*	Heavy cont. *(H)*	Scanty cont. *(S)*
5. Plastic reference	A	Light cont. *(L)*	Light cont. *(L)*	Moderate cont. *(M)*	Light cont. *(L)*	Light cont. *(L)*	Light cont. *(L)*	Scanty cont. *(S)*	Scanty cont. *(S)*
	B	Light cont. *(L)*	Light cont. *(L)*	Light cont. *(L)*	Light cont. *(L)*	Moderate cont. *(M)*	Light cont. *(L)*	Scanty cont. *(S)*	Scanty cont. *(S)*

Note: Contamination levels: (S): < 2.5 CFU/cm^2; (L): 2.5–5.0 CFU/cm^2; (M): 5.0–15.00 CFU/cm^2; (H): > 15 CFU/cm^2. Sides A and B refer to the dipslides two independent sides (both used on the same textile surface).

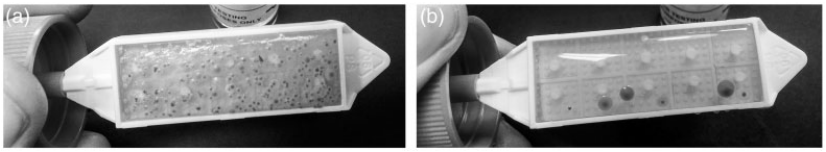

Figure 3. Picture of dipslides after 72-h incubation: (a) heavy contamination and (b) scanty contamination.

surfaces [26], where the limit value for total CFU/cm^2 shall be $\leq$2.5 for evaluating whether the tested surface would pass or fail.

Results

Five different surfaces were tested through a three-week period, and a total of 80 samples (40 before cleaning and 40 after cleaning) were collected in the in situ test. Figure 3 illustrates the difference between a sample of heavy contamination (>15 CFU/cm^2) and a sample of scanty contamination (<2.5 CFU/cm^2). Before cleaning, 67.5% of the sampled surfaces were contaminated on a level ranging between light and heavy contamination, and would thus have failed the microbiological control as stated in valid standard of hospital cleaning [26]. After cleaning, 32.5% of the samples still revealed a light contamination and were above the critical limit value of 2.5 CFU/cm^2 (scanty contamination).

As illustrated in Table 2, the armrest surfaces perform quite differently on the standard cleaning procedure. Only 56% of the traditional textiles are reduced to scanty contamination (S) by the damp wiping, while all the SiO_2-coated textiles were cleaned to an acceptable level.

The traditional textiles had after one week reached a medium level of contamination, and it was only traditional PES that reached the critical limit value after cleaning. In comparison, the SiO_2-coated textiles were after three weeks categorized with moderate and heavy contamination before cleaning, but it was here possible to clean the surfaces to a level of scanty growth.

As it is evident from Table 2, the initial contamination before cleaning was varying, as the armrest has been placed in a real-life situation, where the use and thereby bacteria transmission, are not directly controlled. The contamination level after three weeks has therefore not necessarily increased as this is depending more on the actual use of the chairs and not the accumulation of bacteria over time. In order to compare the different surfaces, and the ability to clean them, Table 3 is relating the cleaning potential to the critical limit value (>2.5 CFU/cm^2), and is evaluating if the surface will pass this microbiological control [26].

As the results indicate, the reference material, the existing armrest of plastic, only reached acceptable level of scanty growth in 25% of samples *after* cleaning, and was in this in situ study actually deficient in maintaining a proper hygiene level. In comparison, the traditional WO and traditional PES passed the

Table 3. The percentage of surface samplings that reach a bacteria level below the critical limit value of 2.5 CFU/cm^2.

Armrest surface	Before cleaning	After cleaning
1. PES *Traditional*	0%	50%
2. PES + SiO_2	62.5%	100%
3. WO *Traditional*	37.5%	62.5%
4. WO + SiO_2	37.5%	100%
5. Plastic reference	25%	25%

microbiological control in 62.5% and 50% of the samples, respectively. Only the SiO_2-coated textiles reached the acceptable level in all of the tests *after* cleaning, and were even below the critical limit in 37.5% and 62.5% of the samples *before* the cleaning procedure.

Discussion

Cleaning of hospital furniture is a high priority for hospital hygiene [26] and as 10% of all hospitalized patients in Denmark are affected by nosocomial infections [27], there is an extensive call for improving the cleaning potential of interior materials. The survival rate of bacteria is generally prolonged on both textiles and hard surfaces [2, 3, 28], and traditional textiles have long been known as a potential bacteria reservoir [1], where the cleaning of the structural surface may be difficult [29].

The immediate solution of replacing traditional textiles with full-coated plastic, as seen in hospitals today, is simultaneously resulting in more clinical and institutional interiors, contradicting the new design visions of healing architecture [18]. Neither the antibacterial textiles seems to be the solution, as the increased scepticism toward these materials is gaining ground especially in Denmark and other Nordic countries [12, 14].

New technologies in the field of passive textile coatings have therefore been proposed with this study, and as it appears from the results of this in situ test, the potential of these technologies seems promising. Even with high initial contamination levels (medium–high contamination), the SiO_2-coated textiles were possible to clean to an acceptable level below 2.5 CFU/CM^2.

In this study, it was only the coated textiles that were possible to clean in accordance to the valid national standard [26], while neither the traditional textiles nor the regular plastic armrest were adequately cleaned by the standard cleaning method.

Only in 25% of the samples, the plastic armrest was below the critical limit value after cleaning, although the bacterial growth was at the borderline in all cases. Based on this in situ test, Noskin et al.'s [29] observations on the challenge of

cleaning traditional textiles are recognized. However, this study found it possible to clean the coated textile, and this improved cleaning potential seems to be worth further studies. Additional long-term in situ studies in new contextual areas are thus considered relevant, while also the disinfection potential of these coated textiles needs to be examined. In Noskin et al.'s [29] study on vancomyocin-resistant enterococci contaminated hospital chairs, a standard disinfectant (quaternary ammonium solution) was not successful in disinfecting the fabric, and alternative disinfection methods thus need to be investigated. In Denmark, the combination of steam and ultrasound has recently been adapted at a Danish hospital for the purpose of disinfecting hospital mattresses [30] and also nontouch room disinfection, based on e.g., damp of hydrogen peroxide, is used in hospitals for disinfection today [31]. These alternative methods for disinfecting the textiles are thus considered worth further attention, and due to the costs of traditional washing, and a general limited washing durability for the SiO_2 coating (five wash cycles, according to modified ISO 6330:2012; 80°C in 10 min), additional research in these aspects would be essential before hospital implementation. Additionally, the abrasion resistance of the coated textiles is an area of concern, where future research and logistic hospital planning should propose new directions for use in the hospital environment. While the tested fabrics itself resist 50,000 Martindale (WO) and 100,000 Martindale (PES), the abrasion resistance of the SiO_2 coating is limited to 15,000 Martindale, before increased wettability is observed. In order to implement these coated textiles in the hospital environment, a new logistic process for maintenance of the coated textile surfaces should therefore be developed. The textiles may for that reason be recoated according to the use of the specific furniture, although this fundamentally adds to the costs of general hospital maintenance. However, architectural research on hospital design shows that the physical environment influences the patients' healing process [32], and here the qualities of interior textiles could potentially promote the architectural experience [18], which would justify the costs of the coatings' maintenance. With this pilot study, focus has been directed on the passive coatings for hospital interiors, and the evaluation of the cleaning potential of SiO_2-coated textiles indicates that the coating provides an easy-to-clean surface that can maintain the high standards of hospital hygiene.

Conclusion

This in situ study on the effect of passive coatings on the surface cleaning potential, showed a substantial difference between the five tested surfaces. Only the SiO_2-coated textiles were possible to clean to an acceptable level below the critical limit value of 2.5 CFU/CM^2. Neither the traditional textiles nor the regular plastic armrest were cleaned to an adequate level. Relating to this study, the use of interior textiles seems to be enabled by applying a passive coating, providing a hydrophobic, easy-to-clean surface that improves the daily cleaning potential.

On the basis of this pilot study, it is therefore advised that research on the application of these passive technologies is progressed. Additional long-term in

situ studies and laboratory tests on disinfection are however still considered pivotal before a final recommendation.

Acknowledgement

The authors of this paper would first of all like to thank the service department at Vendsyssel Hospital, Hjørring, Denmark, for participating in this in situ study. Our acknowledgement also includes Gabriel A/S, for providing textile materials for the tests, and Nobicon A/S for giving the opportunity to test the SiO_2 coatings in the hospital environment.

References

[1] Gao Y and Cranston R. Recent advances in antimicrobial treatments of textiles. *Text Res J* 2008; 78: 60–72.
[2] Neely AN and Maley MP. Survival of enterococci and staphylococci on hospital fabrics and plastic. *J Clin Microbiol* 2000; 38: 724–726.
[3] Lankford MG, Collins S, Youngberg L, et al. Assessment of materials commonly utilized in health care: Implications for bacterial survival and transmission. *Am J Infect Control* 2006; 34: 258–263.
[4] Morsing E and Klamer M. *Reduction of bacteria on textiles*. Report no. 364021. Taastrup, Denmark: Danish Technological Institute, Wood Technology, 2011.
[5] Fijan S and Turk SŠ. Hospital textiles, are they a possible vehicle for healthcare-associated infections? *Int J Environ Res Publ Health* 2012; 9: 3330–3343.
[6] Forster SP, Olveira S and Seeger S. Nanotechnology in the market: Promises and realities. *Int J Nanotechnol* 2011; 8: 592–613.
[7] Lee H, Yeo S and Jeong S. Antibacterial effect of nanosized silver colloidal solution on textile fabrics. *J Mater Sci* 2003; 38: 2199–2204.
[8] Heide M, Mohring U, Hansel R, et al. Antimicrobial-finished textile three-dimensional structures. *Curr Probl Dermatol* 2006; 33: 179–199.
[9] Höfer D. Antimicrobial textiles–evaluation of their effectiveness and safety. In: Hipler U and Eisner P (eds) *Biofunctional Textiles and the Skin*, S. Karger AB, Basel, Switzerland, 2006, p. 42.
[10] Renaud FN, Doré J, Freney HJ, et al. Evaluation of antibacterial properties of a textile product with antimicrobial finish in a hospital environment. *J Ind Text* 2006; 36: 89–94.
[11] Romanò CL, Romanò D, De Vecchi E, et al. Antibacterial finishing reduces hospital textiles contamination. An experimental study. *Eur Orthop Traumatol* 2012; 3: 177–182.
[12] Jensen ET. Statens Serum Institut: CAS-Nyt nr. 105, oktober 2007. Statens Serum Institut, Copenhagen, Denmark, 2007.
[13] Statens Serum Institut. *Nationale Infektionshygiejniske Retningslinjer: For nybygning og renovering i sundhedssektoren [National guidelines on infection control: Construction and renovation in the health care sector]*. Central Enhed for Infektionshygiejne, Statens Serum Institut, Copenhagen, Denmark, 2013.
[14] Mogensen J, Jorgensen PE and Poulsen S. Design innovations and implementation challenges—a case of smart textiles in future hospital interiors. In: *DS 77: Proceedings of the DESIGN 2014 13th International Design Conference,* 2014, pp. 935–945.
[15] Hansen SF and Baun A. When enough is enough. *Nat Nanotechnol* 2012; 7: 409–411.
[16] Silver S, Phung LT and Silver G. Silver as biocides in burn and wound dressings and bacterial resistance to silver compounds. *J Ind Microbiol Biotechnol* 2006; 33: 627–634.

[17] Wijnhoven SW, Peijnenburg WJ, Herberts CA, et al. Nano-silver-a review of available data and knowledge gaps in human and environmental risk assessment. *Nanotoxicology* 2009; 3: 109–138.
[18] Mogensen JE, Fisker AM and Poulsen SB. Interior textiles and the concept of atmospheres—a case study on the architectural potential of textiles in Danish hospital interiors. In: *14th Biennial Symposium Proceedings: New Directions: Examining the Past, Creating the Future*. Los Angeles, USA, 10–14 September, 2014, Textile Society of America [in press].
[19] Türk M, Ehrmann A and Mahltig B. Water-, oil-, and soil-repellent treatment of textiles, artificial leather, and leather. *J Text Inst*. Epub ahead of print 3 July 2014. DOI: 10.1080/00405000.2014.931108.
[20] Rasmussen V and Hansen T. Nanoteknologiske overflader til procesudstyr i levnedsmiddelindustrien—literature review under the project ''Interactions of pathogenic bacteria with new solid surfaces of meat processing equipment''. Report Teknologisk Institut [Danish Technological Institute], Taastrup, Denmark, 2013.
[21] Otter JA. An overview of the options for antimicrobial hard surfaces in hospitals. In: Borkow G (ed) *Use of Biocidal Surfaces for Reduction of Healthcare Aquired Infections*. Springer International Publishing, Switzerland, 2014, p.137.
[22] Connor S. The miracle spray-on glass that stops the bugs. *The Independent*, 9 August 2010.
[23] Broekhuizen Fv. Nano in Furniture—State of the art 2012. Report, IVAM UvA BV. Amsterdam, Holland, 2012.
[24] Broekhuizen Fv. Working with NP(R)-coatings at NanoPool GmbH—annex to the report: nano in furniture, state of the art 2012. Report. IVAM UvA BV. Amsterdam, Holland, 2012.
[25] NHS. Smart solutions for HCAI—evaluation report: NanoPool surface coating. NHS (National Health Services), Report. TrusTECH, UK, 2013.
[26] DS 2451-10: Infection control in the health care sector—part 10: requirements for cleaning. Danish Standard, 2014.
[27] Leth RA and Møller JK. Udviklingstendenser i forekomsten af hospitalserhvervede infektioner og antibiotikaforbrug i Århus Amt [Development tendencies in the incident of hospital acquired infections and the use of antibiotics in Århus]. *Ugeskr Laeger* 2006; 168: 1129–1132.
[28] Huang R, Mehta S, Weed D, et al. Methicillin-resistant Staphylococcus aureus survival on hospital fomites. *Infect Contr Hospital Epidemiol* 2006; 27: 1267–1269.
[29] Noskin GA, Bednarz P, Suriano T, et al. Persistent contamination of fabric-covered furniture by vancomycin-resistant enterococci. Implications for upholstery selection in hospitals. *Am J Infect Control* 2000; 28: 311–313.
[30] FORCE Technology. Hospital mattress cover, http://sonosteam.dk/cms/site.aspx?p=13623 (accessed 28 October 2014).
[31] Statens Serum Institut. *Nationale infektionshygiejniske retningslinjer: For desinfektion i sundhedssektoren [National guidelines on infection control: Disinfection in the health care sector]*. Central Enhed for Infektionshygiejne, Statens Serum Institut, Copenhagen, Denmark, 2014.
[32] Ulrich RS, Zimring C, Zhu X, et al. A review of the research literature on evidence-based healthcare design. *Health Environ Res Design J* 2008; 1: 61–125.

PAPER D

Interior Textiles and the Concept of Atmospheres – A Case Study on the Architectural Potential of Textiles in Danish Hospitals Interiors

Jeppe Emil Mogensen, Anna Marie Fisker & Søren Bolvig Poulsen

Introduction

In the planning and development phase of new hospitals, built these years, a new tendency has gained ground, and concerned with the patients' hospital experience, the design concept *healing architecture* is introduced[1,2]. As a contrast to contemporary modern hospitals, often criticised of being too clinical and institutional[3], the vision of healing architecture is set to promote the patients healing process through stimulating and accommodating physical surroundings[2,4,5].

Nevertheless, while the overall architectural focus has turned towards more experience-based and patient-supportive environments, another tendency is seen in the interior scale of Danish hospitals. Here the traditional textiles are being phased out, as the cleaning process is optimised to greater efficiency. Curtains and upholsteries that earlier resembled a familiar and homely environment, are now replaced by interior window blinds and plastic coated furniture that often imbue an even more institutional and clinical atmosphere.

Although this reduced use of interior textiles may share financial benefits of an improved efficiency in cleaning and maintenance, it is concurrently conflicting with the overall visions of healing architecture. From an architectural perspective, it seems obvious that if the patients should gain from this vision, suggesting a more aesthetic approach to the experience of hospital architecture, it is essential that also the interior scale are prioritised and designed accordingly. The visionary design are nevertheless difficult to fulfil, if the materials for use are limited to plastic, vinyl and gypsum, as we see in hospitals today.

By observation of the interiors of Danish hospitals[6], the purchasing of furniture and textiles seems to be mainly based on rational priorities of cleaning and maintenance; and while these aspects are formulated in guidelines and standards[7] the more experience-based and aesthetic aspects, that by their intangible nature are more difficult to articulate, appears de-emphasised in the requirement specifications for new furniture materials[8]. This has promoted the use of plastic coated upholsteries, confining the patient comfort, and the hospital atmosphere. In the authors' perspective, this diminished attention on interior materials is challenging the visions of healing architecture, and in order to promote the future design of hospital interiors, the awareness of the textiles' architectural potential should ideally be enhanced.

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[1] Kjeld Vindum et al. "Hav tillid – En rundbordssamtale med fire hospitalsarkitekter", *Arkitekten,*113 (7). (Arkitektens Forlag 2011): 40-37.

[2] Anne Kathrine Frandsen et al., *Helende Arkitektur,* (Aalborg: Institut for Arkitektur, Design og Medieteknologi, Aalborg Universitet), 2009.

[3] Cor Wagenaar, "The Architecture of Hospitals" in The Architecture of Hospitals, ed. Cor Wagenaar (NAi Publishers 2006): 11-19.

[4] Kim Dirckinck-Holmfeld et al., *Sansernes Hospital*, (Arkitektens Forlag 2007).

[5] Roger Ulrich et al., "A Review of the Research Literature on Evidence-Based Healthcare Design", *Health Environments Reseach & Design Journal,* 1(3) (2008): 61-125.

[6] Research by the authors in regards to the PhD project: "Smart Textiles in Future Hospitals", conducting exploratory interviews and observations on Danish Hospitals.

[7] Danish Standard, *DS2451-10, Infection control in the health care sector – part 10: Requirements for cleaning.* (Dansk Standard 2011).

[8] Gentofte Hospital, *Design Manual – Gentofte Hospital,* (Gentofte Hospital 2014).

By readdressing focus on textiles in hospital interiors, the purpose of this paper is thus to accentuate the textiles' architectural potential, and to explore if the theoretical framework of *atmosphere*, can be a way to articulate the qualities of textiles in regards to hospital interiors. This will be done by conducting an analytic case study on health care related interiors, aiming to unfold the textiles qualities, and to present these in a new research-based conceptual framework that supports future decisions on the use of textiles in hospital interiors.

Theoretical perspective – introducing the concept of atmosphere

With this paper focus is directed towards the architectural potential of textiles, and concerned with the visions of healing architecture, as to stimulate the healing process through positive and stimulating architectural experiences, we will in this paper explore how the concept of atmosphere can be used as the theoretical framework for accentuating and articulating these qualities in regards to hospital interiors. This philosophical concept is considered a relevant point of departure for discussing the immediate experience of space that is closely linked to the discussion of architectural quality.

By introducing the concept of atmosphere in architectural research, focus has been directed towards the experienced quality of space, understood as a holistic interplay between a wide range of both physical and social design aspects[9]. It is these design aspects of form, colour, light, acoustics, materials and texture; combined with social elements of symbols, culture, and behavioural norms; that mutually affect each other and defines the space and the architectural experience – the atmosphere.
"The notion of atmosphere always concerns a spatial sense of ambiance"[10], and as a concept in architecture and interior design, atmospheres are an interesting subject. The presence of atmospheres is rarely doubted, and neither is its importance. Through language, spaces are skilfully defined as joyful, serious, majestic, cold, or cosy, but although the surrounding atmosphere may be easily described, the term atmospheres is used because the feeling is so peculiarly intangible.[13,11]

German philosopher Gernot Böhme defines *atmosphere* as a new aesthetic concept that relates to the sensuous experience of space, architecture and design:
"Atmosphere is something between the subject and the object; therefore, an aesthetics of atmosphere must also mediate between the aesthetics of reception and the aesthetics of the product or of production."[10]
With this statement, Böhme also touches upon the *presence of atmosphere*, as something floating between us as sensing bodies and the physical objects of the surrounding space. Thus, experiencing an atmosphere is to perceive the surroundings with all our senses, and to be mindfully aware of the feeling in that particular space.
This sensitive experience of space is naturally relating to the personal sense of it, namely the mood, but *"the space also has an objective constitution and much of what belongs to it is not part of [the personal] sensitivity."*[12]

[9] Gernot Böhme, "Atmosphere as Mindful Physicale Presence in Space", *Oase #91–Building atmosphere,* (2013): 21-32.
[10] Gernot Böhme, "Atmosphere as an Aesthetic Concept", in *Daidelos 68 "Constructing Atmospheres,* ed. G. Confurius et al. (Daidalos 1998): 112.
[11] Gernot Böhme, "Atmosphere as the Fundamental Concept of a New Aesthetics", *Thesis Eleven* 36(1), (1993): 113-126.
[12] Böhme, "Atmosphere as an Aesthetic Concept" 27.

The experience of atmospheres is according to Böhme thus considered quasi-objective, understood as a subjectively based experience, we still are able to communicate and discuss with others. As in the theatre, where the stage set is designed to imbue the audience with a certain atmosphere, which would be pointless if the atmosphere were a purely subjective experience.[13]

Architectural atmospheres are fundamentally an aesthetic concept, dealing with the immediate experience of the physical environment, as it affects our perception of space in a most essential manner. While the experience of space may be personal, it still shares quasi-objective perspectives, relating to our cultural and sensuous aesthetic perception, and from these factors of atmosphere, we may advance our understanding of the architectural potential of textiles.

Materials and the concept of atmosphere

While Böhme's philosophical approach provides a fundamental understanding of the concept of atmosphere and the significance in regards to architectural experiences, we will need to relate more closely to the field of architecture, in order to link the aesthetic concept to the use of architectural materials. In 2006, Swiss architect Peter Zumthor, published his well-cited contribution to the discussion on architectural atmospheres, in which he elaborates on his approach to architecture as a purpose of providing spaces of atmosphere. Where Böhme is leaving his elaboration on atmospheres in architecture on a more abstract level, Zumthor as a practitioner goes further and identify a range of architectural aspects, which he consider when working with atmospheres[14].

Zumthor is in his understanding of atmosphere closely related to the philosophical writings of Böhme, emphasising that *"we perceive atmosphere through our emotional sensibility"*[15], and that this emotional response to the surrounding space is founded by an immediate, spontaneous appreciation and unconscious perception.

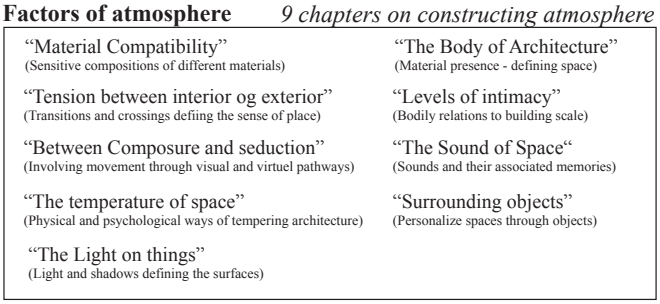

Figure 1. Architectural factors of atmosphere. Peter Zumthor (2006).

In Zumthor's approach to the construction of atmospheres, he defines a very sensuous and aesthetic approach to the work with architectural atmospheres, with a strong emphasis on the materials and the deliberate composition of their inherent qualities. With references to the

[13] Gernot Böhme, "The Art of the Stage Set as a Paradigm for an Aesthetics of Atmospheres", *Ambiances: Environments Sensible, Architecture Et Espace Urbain,* (2013): 2-8.
[14] Zumthor, *Atmospheres.*
[15] Zumthor, *Atmospheres, 13.*

body of architecture, as the physical frame of architecture, Zumthor is explaining how the material presence of architecture, has a sensual effect on him, and how he understands the combination of different materials as one of the great secrets of architecture[14]. The use of materials to define and communicate the architectural space, are fundamentally an essential part of the way we perceive architecture,[14,16,17] where the natural materials share an authenticity that cannot be reached with the machine-made materials of today[16].
The textiles may from this theoretical perspectives be considered a potential generator of atmospheres, and to unfold how this unique material contribute to the experience of space, we will relate to a case study to accentuate and articulate the architectural potential of textiles in regards to hospital interiors.

Case Studies

Acknowledging that the interior objects affect the atmosphere,[18,19,20,21] we will in this case study focus on how textile-based objects are applied in health care related architecture, and analyse how they contribute to the experienced atmospheres. The outcome of this case study is aiming to accentuate specific design qualities of textiles, and to provide a new conceptual framework to better articulate the architectural qualities of textiles in regards to future hospital design.

The method of *case studies* is generally intended as the empirical inquiry to investigate a contemporary phenomenon within its real-life context,[22] which makes it well operable for the study on the architectural potentials of textiles. The cases are thus related to contemporary health care architecture, where the use of textiles constitutes a significant aspect in the interior design. It is conceivable that more inspiring or aesthetically stimulating cases of textile interiors could be found outside the health care sector, but as the *"architectural quality is perceived in relation to its context and its special preconditions"*[23], the cases should relate to this particular context. The cases for this study is therefore composed by a recently build Cancer Counselling Centre in Herning, Denmark and a Hospice at Ringkøbing Fiord, Denmark. In both these cases, interior textiles have been applied as a deliberate design strategy to define a more accommodating atmosphere, with associated references to the visions of healing architecture. The analysis of both cases is based on a visit to the locations in order to experience the atmosphere personally, and to analyse more specifically how the textile based objects relates to this overall atmosphere. As the main focus has been to accentuate the qualities of the textile based objects in regards to the concept of atmosphere, this approach is considered achievable, although it may be discussed if an observing researcher is having the same experience of atmosphere as the diseased patients, for whom the design is intended.

[16] Juhani Pallasmaa, *The Eyes of the Skin: Architecture and the Senses*, (Wiley 2005).
[17] Steen Eiler Rasmussen, *Om at Opleve Arkitektur*, (København: G.E.C. Gads forlag 1966).
[18] Böhme, "Atmosphere as the Fundamental Concept…".
[19] Böhme, "Atmosphere as Mindful Physical Presence…".
[20] Zumthor, *Atmospheres.*
[21] Juhani Pallasmaa, "Atmosphere, Compassion and Embodied Experience", *Oase #91 – Building atmosphere,* (2013): 33-53.
[22] Linda Groat and David Wang, *Architectural research methods, (*Wiley 2002): 418, citing Robert K. Yin, *Case Study Research, Design and Methods* (2009).
[23] Magnus Rönn, "Architectural Quality in Competitions. A Dialogue Based Assessment of Design Proposals", *FORMakademisk* 4(1), (2011): 106.

Case 1: Cancer Counselling Centre
Livsrum, Herning, Denmark

Figure 2. Pictures from Livsrum Herning, Denmark. Image by: Jeppe Emil Mogensen

The newly opened Cancer Counselling Centre in Herning, Denmark is designed by architect Claus Pryds, and provides adjacent facilities for support of cancer patients and their families. By its exterior appearance, the house is reinterpreting the classical archetypical Danish house, which most people associates with "home". When moving inside, the balance between the public and homely atmosphere is expressed in the scale of the interior spaces as well as in the *material compatibility*. The new extension has walls of wooden veneer and polished concrete floors, providing an untypical conceptual simplicity that is not associated directly with either a private home or the hospital. By the choice of materials, you are by this special character reminded of where you are, which in a phase of reiterated stays at doctors and the hospital, must give a certain comfort and inner peace. In contrast to this *architectural body* of hard surfaced veneer walls and the concrete floor, the textile-based objects are contributing with recognisable and homely associated elements, balancing the visual and sensuous perception of the interior atmosphere, while ensuring a material harmony. It is therefore the significant balance between the smooth veneer and the textiles sensuous movement that, together with the additional surrounding objects, defines the *level of intimacy*, and the experienced atmosphere of quietness, attention and most importantly care.

Despite giving some important acoustic advantages, the textiles are applied in different areas of the house to define some physical touch points with the users. In the lounge areas, the upholstered furniture acts as contrast to the other materials, and defines a physical space as well as a supportive zone for conversation. The associate pillows and blankets in these lounges are unconsciously recognised and identified as homely objects, providing an ideal setting social relations as an internal space-in-space for contemplation and social support. The curtains are traditionally used as shades and screens for adjusting the direct sunlight, but are also applied as hanging screens in the room. Again providing a textural contrast to the hard surfaced veneer, the vertical textile walls imitate movements through the unruly falling shape and spatial appearance. Fundamentally, the curtains are offering the users a certain degree of individual control of the environment. Whether they would like to control the lightning, shadows, views or colour perception by adjusting the different window curtains, the users have a personal influence on the architectural experience and the room atmosphere. This provides a sense of control of the physical structure, and the use of textiles is relating closely to the architectural vision of balanced homeliness, and contributes to the experience of a warm, supportive and caring atmosphere.

Case 2: Hospice
Anker Fjord, Ringkøbing, Denmark

Figure 3. Pictures from Anker Fjord Hospice, Denmark. Image by: Jeppe Emil Mogensen

Anker Fjord Hospice was opened in 2006, setting new standards for the modern hospice, and for well-designed health care architecture. The vision of the hospice, as a place where dying patients may anchor in the final phase of live, has resulted in the overall form of the building, where the anchor arms contains the 12 apartments. The basic materials of the architectural body is restricted to the use of prevalent material types, where the white walls and perforated acoustic ceilings, provide a certain characteristic that may be associated with more well-known typological health care architecture. This essentially optimises the daily maintenance and facilitates the functional concerns of handling bedbound patients. Sharing immediate references to typological modern hospitals, the *levels of intimacy* at Anker Fjord are instead unfolded in the interior scale of the hospice. Here textiles and textile-based furniture apply to the *material compatibility*, as a significant part of the home-like atmospheric concepts, experienced at Anker Fjord. These accommodating arrangements, contributes to the warm and including atmosphere, turning the otherwise sombre and serious mood to a surprisingly remarkable and warm life-affirming experience. In this confident and safe environment, the attentive team of staff has managed to direct the primary focus on life rather than death, and the vision of not resembling a hospital seems succeeded.
The common facilities are situated around smaller central lounges, where textile weaver Puk Lippmann's remarkable landscape carpet is placed. The carpet contribute in the hall area by creating a clear zone of accommodation, and by its characteristic texture and colour composition, representative elements from the surrounding nature are elegantly included in the interior of the hospice. The differentiated weaving gives the carpet a three-dimensional surface, providing a multisensory synesthetic experience, and by uses of references from nature the carpet creates a *transition between the interior and exterior*.
In addition to the central common areas in the atrium, the anchor arms provide smaller living areas, shared amongst the surrounding patient apartments. Here a smaller kitchen and an adjoining lounge setting create a more homely atmosphere, supported by the deliberately well-designed environment. The classic sofas designed by Finn Juhl (1912-1989), decorated with blankets and pillows as textile accessories, are divided from the kitchen by bookcases and define a distinctive zone. Although the scale of this setting is limited, the recognisable homely elements and the use of textiles as furniture, curtains and accessories, promotes a relaxed and familiar atmosphere, facilitating conversations between patients and relatives from the different apartments. Anker Fjord is with its special character, contributing to an ideal hospice setting, and despite the typological health care related associations, the carefully designed interior and the manifold use of textiles promotes an accommodating and safe atmosphere.

Findings and discussion

Having presented these two case studies, where focus has been directed on the experience based architectural potentials of interior textiles, we will in the concluding part of the paper link the findings to the future of Danish hospitals. It should be mentioned that the case studies are not intended to present all the various qualities of textiles, but rather to accentuate the potentials that could be linked with the visions of healing architecture in terms of improving the experienced architectural atmosphere. It is, nevertheless, clear that the textiles contribute with a wide range of architectural potentials in the case studies. First of all improving the acoustic experience, relating to Zumthor's definition of *'the sound of space'*, the textiles are reducing the noise and provides a calm and relaxing environment for contemplation and conversation. The sounds are an important aspect of the experienced atmosphere, and where hospitals today often are found to be noisy and disturbing[24], textiles may provide spaces and recesses for private conversation - also in the hospitals. Also the *'light on things'* are closely related to the use of interior textiles. As curtains, the textiles control the direct sunlight, the diffuse light and shadows, and filtering the daylight, the light experience is strongly influenced by the use of textiles. Today blinds in the hospital windows are casting fixed sharp-edged shadows that relates to the cold interiors, while an elegant curtain instead could imbue the interior with a soft and gentle touch of light and shadow. The curtains furthermore relates to the *'tension between exterior and interior',* providing visual shading or framed views, that enable the patients and users to control and define their personal experience of space. In both cases textiles are used to define recesses and zones, acting as a spatial divider of the *'body of architecture',* and as a light and elegant contrast to the hard surfaces of the more traditional material, this harmonic composition provide aesthetic and functional balance in the *'material compatibility'*.

Relating solely on *cold materials* in the hospital interior, the atmosphere is not likely to appear accommodating and stimulating, and here the use of textiles could balance this current institutional perception and provide recognisable and sensuous pleasing materials to the hospitalised patients and their visitors. Fundamentally, the dynamic nature of textile structures produces variability and changeability in the architectural experience, and involving virtual imitations of movement, the sculptural falling shape of hanging curtains and textile objects dissolves the static nature of architecture. While providing tactility and details, the textiles compliment the architecture with a sensuous effect that potentially embrace the patients with a human architectural touch, and this haptic feature of textiles are considered a significant aspect of unfolding the *'levels of intimacy'* as the bodily relations to the building scale. Finally, the textiles are included in the interior as recognisable '*surrounding objects'* that personalises space, referring to well-known homely environments, relating again to the *'level of intimacy'* to balance the experience of large-scale health care systems.

Based on these findings, a new conceptual framework on the architectural potential of textiles in hospital interiors is proposed. By summarizing the case study findings, the specific architectural potentials of textiles are related to the factors of atmosphere, and the specific preconditions of the hospital context.

[24] Rikke Gundersen, "Støjgener værst på Sygehuse og Slagterier", *Ugebrevet A4,* (March 21, 2013), accessed Oktober 20, 2014, http://www.ugebreveta4.dk/stoejgener-vaerst-paa-sygehuse-og-slagterier_14123.aspx

Conceptual Framework

Architectural Potential of Textiles in Hospital Interiors

Case Study Findings *Interior textiles are:*	**Factors of atmosphere** *(Zumthor 2006)*	**Notes on contextual preconditions** *Case study findings related to the hospital context*
- Improving the acoustics	*"The Sound of Space"*	Noise of medical equipment and other patients are challenging the need for calmness and rest, and the wish for private conversations. Acoustics are therefore traditionally an aspect of healing architecture (Frandsen et al. 2009).
- Providing flexible screens and shades	*"The Light on things"* *"Tension between interior and exterior"*	The possibility to control the physical environment is highlighted as an important aspect of healing architecture (Ulrich 1997), and controlling the daylight and diffuse light in the physical environment will affect the room atmosphere and the architectural experience.
- Defining zones and a sense of place	*"The Body of Architecture"*	By virtuelly and physically defining smaller zones with textile based objects, a private place may be defined in the otherwise large scale hospitals.
- Providing variability and changeability	*"The Body of Architecture"*	Hospitals are today built as small cities and variability in different areas of the hospital may support wayfinding (Frandsen et al. 2009) and define the different wards and areas with a distinctive sense of space.
- Increasing the sensuous and tactile qualities	*"Material Compatibility"* *"The temperature of space"*	Materials of hospitals today are often limitied to plastic, vinyl and gipsum. As a contrast material to these hard surfaced elements, textiles may balance the sensory perception of vision and touch. Also giving a warmer impression of the environment compared to the otherwise cold materials.
- Relating to homely references	*"Surrounding objects"* *"Levels of intimacy"*	The interior objects of most hospitals are often promoting the institutional and clinical impression of the physical environment, and here textiles may relate to homely references and increase the levels of intimacy and human scale attempting to personalise the surrounding space.

Figure 2. Findings from the case study related to Zumthor's architectural factors of constructing atmospheres, and the authors notes on how the hospital potential in regards to the vision of healing architecture.

In today's hospitals, criticised of being institutional and clinical, the current architectural experience is most likely to improve by the use of interior textiles. In the case studies, the textiles provided both functional and aesthetic perspectives, and shared a significant role in defining the experienced atmosphere. As discussed, most of these textile qualities could also be utilised in regard to hospital architecture aiming for improved healing outcomes. Thus, if patients in future hospitals should benefit from the visionary intentions of healing architecture, the use of interior textiles could be a way of balancing the institutional experience of the traditional material compositions. Of certain interest would be spaces already aiming for relaxing and distressing atmospheres, including waiting areas, hallways and social day rooms, where the accommodating, homely atmosphere is already requested by patient reports. [25,26]

Conclusion

The overall purpose of this paper has been to accentuate the textiles' architectural potential, and having presented the case studies and the research-based findings in a new conceptual framework, the discussion on the textiles' use in hospital interiors is now initiated.
The concept of atmosphere has in this regard emerged as an appropriate theoretical framework, focusing on the immediate architectural experience, which also includes the intangible aesthetic dimensions that today are found difficult to articulate and prioritise in the design of hospital interiors. The atmosphere has a major influence on the perception of the surrounding environment, and consequently for the experience of healing architecture.

[25] Bryan Lawson, Michael Phiri and John Wells-Thorpe, *The Architectural Healthcare Environment and its Effects on Patient Health Outcomes,* (NHS Estates 2003).
[26] Danske Patienter, *Fremtidens Sygehusbyggeri – Patienternes Perspektiv,* (Danske Patienter 2009).

Concerned with the textiles' influence on the architectural experience, Zumthor's and Pallasmaa's more practice related interpretation of atmosphere, progress the concept to an operational level, on which basis the architectural potentials of textiles has been addressed. From this theoretical perspective, the sensuous and tactile dimensions of architecture are considered essential, and the concept of atmosphere is thereby deployed to articulate the aesthetic and experience-based qualities of textiles through analytical case studies. In regards to exploring the aesthetic dimensions of healing architecture, the concept of atmosphere is thus found to be an appropriate theoretical perspective, which also could be used in other fields than textiles.

As presented in the conceptual framework, it is especially the tactile and sensuous qualities of textiles that will promote the current clinical and institutional atmosphere of contemporary hospitals. However, besides these aesthetic dimensions, the textiles are also found to contribute with more functional aspects, where acoustic improvements, control of daylight and flexible decoration of interiors are related to the inherent qualities of textiles, supporting the positive experience of the hospital environment.
Even though some of the architectural potentials, accentuated through the case studies, may be claimed to be *basic* findings, this theoretical approach, has provided a new research-based conceptual framework to promote the articulation of the textiles' qualities. In the decision process on future hospital design, this framework is considered relevant for decision makers and hospital managers, who are not usually accustomed to deal with design related aspects. As seen in current practice, the aesthetic aspects of interior design are often under prioritised compared to the more strictly defined rational and functional standards of hospital cleaning, etc., and here the conceptual framework could be a tool to better articulate and recognize the aesthetic and experience-based qualities of interior textiles. Further research, in the field of materials and healing architecture, would therefore be advisable to further progress the aesthetic experience of hospital interiors. With this paper we have initiated the discussion and with strong hopes for future hospital design, we advise that the current rational and functional considerations on use of interior materials will be balanced with the experience-based aspects, also relating to the aesthetic dimensions of architecture and design. The conceptual framework, suggested in this paper, could in this regard be a tool to articulate the challenge of combining these aesthetic, functional and technical demands of hospital interior design. The awareness of the materials influence on the perceived hospital atmosphere is considered essential in order to meet the visions of healing architecture, as the interior scale of the hospital is relating closely to the patients' architectural experience. From this perspective, we at least hope that the textiles' architectural potential will be reconsidered before deciding how to furnish our future Danish hospitals.

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References

Böhme, Gernot. "Atmosphere as Mindful Physical Presence in Space." *Oase #91 - Building Atmosphere.* 2013: 21-32.

Böhme, Gernot. "Atmosphere as the Fundamental Concept of a New Aesthetics." *Thesis Eleven* 36 (1) (1993): 113-126.

Böhme, Gernot. "The Art of the Stage Set as a Paradigm for an Aesthetics of Atmospheres." *Ambiances.Environnement Sensible, Architecture Et Espace Urbain*. (2013): 2-8

Böhme, Gernot. "Atmosphere as an Aesthetic Concept." In *Daidalos "Constructing Atmospheres"*, edited by G. Confurius, J. Bond, A. Schmedding, G. Auer, U. Conrads, G. Mattenklott, W. Oechslin and J. Pieper. 68th ed., (1998): 112-115.

Dansk Standard. *DS 2451-10: Styring Af Infektionshygiejne i Sundhedssektoren - Del 10: Krav Til Rengøring*: Dansk Standard, 2011.

Danske Patienter. *Fremtidens Sygehusbyggeri - Patienternes Perspektiv*. Danske Patienter, 2009.

Dirckinck-Holmfeld, Kim, Peter Michael Hornung, Henning Damgaard-Sørensen, and Lars Heslet. *Sansernes Hospital.* Arkitektens Forlag, 2007.

Frandsen, Anne Kathrine, Micahel Mullins, Camilla Ryhl, Mette Blicher Folmer, Lars Brorson Fich, Turid Borgestrand Øien, and Nils Lykke Sørensen. *Helende Arkitektur*. Aalborg: Institut for Arkitektur og Medieteknologi, Aalborg Universitet, 2009.

Gentofte Hospital. *Design Manual - Gentofte Hospital*: Gentofte Hospital, 2014.

Groat, Linda and David Wang. *Architectural research methods.* Wiley, 2002.

Gundersen, Rikke. "Støjgener værst på Sygehuse og Slagterier", *Ugebrevet A4,* (March 21, 2013), accessed Oktober 20, 2014, http://www.ugebreveta4.dk/stoejgener-vaerst-paa-sygehuse-og-slagterier_14123.aspx.

Lawson, Bryan, Michael Phiri, and John Wells-Thorpe. *The Architectural Healthcare Environment and its Effects on Patient Health Outcomes*. NHS Estates, 2003.

Mogensen, Jeppe, Poul-Erik Jorgensen and Søren Bolvig Poulsen. "Design Innovations and Implementation Challenges - A Case of Smart Textiles in Future Hospital Interiors", *DS 77: Proceedings of the DESIGN 2014 13th International Design Conference*, (2014): 935-945.

Pallasmaa, Juhani. "Atmosphere, Compassion and Embodied Experience." *Oase #91 - Building Atmosphere*, (2013): 33-53.

Pallasmaa, Juhani. *The Eyes of the Skin: Architecture and the Senses.* Wiley, 2005.

Rasmussen, Steen Eiler. *Om at Opleve Arkitektur*. 2nd ed. København: G.E.C.Gads forlag, 1966.

Riisberg, Vibeke. *Arbejdsnotat Research & Workshop - Tekstiler På Fremtidens Sygehuse*: Kolding Designskole, 2011.

Rönn, Magnus. "Architectural Quality in Competitions. A Dialogue Based Assessment of Design Proposals." *FORMakademisk* 4 (1), (2011): 100-115.

Ulrich, Roger S. "Pre Symposium Workshop: A Theory of Supportive Design for Healthcare Facilities." *Journal of Healthcare Design* 9. (1997): 3-7.

Ulrich, Roger S., Craig Zimring, Xuemei Zhu, Jennifer DuBose, Hyun-Bo Seo, Young-Seon Choi, Xiaobo Quan, and Anjali Joseph. "A Review of the Research Literature on Evidence-Based Healthcare Design." *Health Environments Research & Design Journal* 1 (3). (2008): 61-125.

Vindum, Kjeld, Sofie Bjerring, Tom Danielsen, Finn Sørensen, Lars Steffensen, and Wilhelm Berner-Nielsen. "Hav Tillid - En Rundbordssamtale Med Fire Hospitalsarkitekter." *Arkitekten* 113 (7). (2011): 40.

Wagenaar, Cor. "The Architecture of Hospitals." In *The Architecture of Hospitals*, edited by Cor Wagenaar. NAi Publishers, 2006: 11-19

Zumthor, Peter. *Atmospheres : Architectural Environments - Surroundins Objects*. Basel: Birkhäuser, 2006.

PAPER E

Interior design and healing architecture: A mixed-method study on the patients' preferences for interior textiles and textile-based furniture for future hospitals

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Abstract

Hospital design is today influenced by the design concept healing architecture, stating that the patients' healing process is promoted through accommodating physical surroundings. However, despite the increasing amount of research in the field of healing architecture, research on interior design and materials are rather limited. To compliment research in hospital interior design with particular focus on the use of interior textiles, this pilot study explores if the patients' preferences for more home-like hospital interiors can be linked to a preference for textile-based furniture and materials.

Through a mixed-method study, 43 patients from the outpatient-lung department at Hospital Vendsyssel, Denmark were presented with different types of furniture and materials and were asked about their preferences. Additional questions on their experience of the hospital interior were asked to guide the interpretation of the quantitative and qualitative data.

21% of the participants requested interior design improvements, and had a pronounced preference for the textile-based furniture and materials. For this particular group, the link between home-like hospital interiors and textile materials were thus established. However, a major group of the participants were satisfied with the existing interior, and preferred the furniture style of the traditional hospital interior. As this contradicts with existing literature on patients' design preferences, reasons for this were explored through the qualitative analysis. The preference for traditional hospital interiors were thereby linked to the patients' confined expectations of the hospital appearance. From this pilot study, the paper suggests new approaches and methodologies for further studies to explore the potential of material improvement in hospital interiors. Although participatory preference studies provide a good indication on the users' experience, more profound design studies are needed to unfold the experienced value of design aspects in hospital environments.

Keywords: Health-care design, mixed-methods, participatory approaches, furniture, textiles, healing architecture

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Introduction

Throughout Western Europe, the hospital buildings are in these years undergoing a significant modification. Hospital design and its effect on the patients' healing process have been recognised, and the design concept *healing architecture* is gaining ground (Ulrich *et al,* 2008; Frandsen *et al,* 2009). However, despite the still increasing amount of research in the field of healing architecture (Frandsen *et al,* 2009; Ulrich *et al,* 2008), academic knowledge on hospital interior design is still rather limited (Douglas and Douglas, 2004). Existing literature suggest that a more 'home-like' interior is preferred to support the patient-friendly experience (Horsburgh Jr, 1995; Lawson, Phiri and Wells-Thorpe, 2003), but the term 'home-like' has not been linked to particular interior design solutions. The interior, however, frames our behaviour, mood and general wellbeing, and the home-like interior also relates to the use of materials, furniture and objects that generate the room atmosphere (Böhme, 1993; Zumthor, 2006). Interior textiles may from this perspective be a potential material that can provide new aesthetic qualities to the hospital environment. Textiles are today replaced by plastic-coated upholsteries that enhance the clinical and institutional hospital atmosphere, while new cleaning-friendly textiles exist that could promote the home-like experience by providing tactile and recognisable elements to the hospital interior (Mogensen, Jorgensen and Poulsen, 2014; Mogensen, Fisker and Poulsen, 2014). However, so far this awareness on hospital interiors and the use of furniture, materials and textiles for generating a home-like atmosphere has not been acknowledged and the patients' preferences has not been studied.

To compliment research in the field of interior design and healing architecture, this pilot study will thus focus on the use of textiles in hospital interiors, and will explore if the patients' general preference for home-like interiors can be linked to a preference for interior textiles in the hospital environment. Through interviews with patients in a Danish hospital, this paper presents a pilot study exploring the patients' material and furniture preferences. Based on these results, the paper discusses new approaches to conduct design-based research on hospital interior design.

Methodology

Setting and participants

The study is explorative and based on a mixed-method approach, conducting interviews with patients in a regional Danish hospital during April and May 2014. In a waiting room at the outpatient lung department at Hospital Vendsyssel, 43 patients receiving ambulant treatment were interviewed, and asked about: their preferences for furniture; their preference for textile materials; and their general impression of the hospital interior design. The lung department was chosen for its broad variety of patients covering COPD patients, allergic patients and chronically diseased patients under ambulant observation. The patients were briefly informed about the

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interview but not about the specific focus on furniture and textiles. The group ranged between 18-75+ years of age, and counted 23 females and 20 males.

Interview setup

In order to collect mixed-method data on the patients' furniture and material preferences, the interviews included both close-ended questions for the quantitative data set and open-ended questions for the qualitative analysis. Cardboards with pictures (12x15 cm) of five different chairs ranging from low degree of textiles to a high degree of textiles (see table 1) were presented for the participants. After a moment looking through the different pictures, the patients were asked about their preference for a future hospital dayroom. This exercise was follow by open-ended questions, where the participants were asked about their reason for selecting the chair.

Table 1. Chairs presented for the participants

 **Chair 1**	 **Chair 2**	 **Chair 3**	 **Chair 4**	 **Chair 5**
The Bern Chair Wooden frame of lacquered beech, with plastic upholstery. A typical design for traditional Danish hospital interiors.	**Wegner GE-290** Wooden frame of oak, upholstered with a soft woollen fabric. The shape and the wooden frame associate with hospital furniture.	**Wegner AP-27** A full upholstered seat and back, with wooden legs and armrests. The chair balances the home-like and the institutional design tradition.	**Polo** Full upholstered and soft armchair. Associate with traditional chairs for a living room. Not typical for the hospital environment.	**Spectra** A lay back armchair with a very soft seating. Included to indicate for the patients that new thoughts and ideas on future hospital design is allowed.

Note: In this table, the chairs range from a typical hospital chair as chair 1, and a very textile-based chair as chair 5. When presented for the patients, changing the numbers of the chairs randomised this range.

The second part of the interview focused on textile materials, and introduced five different physical samples (15x22 cm). The materials ranged from easy-to-clean plastic upholsteries to coarse woollen fabrics (see table 2). The participants were asked about their preference, and open-ended questions were asked in order to understand the reason behind these preferences.

Table 2: Textiles presented for the participants.

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	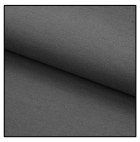	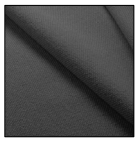		
Material A	**Material B**	**Material C**	**Material D**	**Material E**
Wafer by Maharam (Kvadrat). The surface is 100 % polyurethane. A dull surface with a machine made structure of smaller dots. Represents the easy-to-clean plastic upholsteries used at hospitals today.	**Plot (Kvadrat).** 100 % Trevira CS, Polyester. The textile appears to be very light, and represents a material that with a smooth surface would seem to be easy to maintain.	**Hallingdal 65 (Kvadrat).** 100 % wool. A semi-coarse texture, representing traditional woollen upholstery that has been used for Danish classical furniture.	**Outback (Kvadrat).** 80 % wool. Boucle yarn in both directions gives an unstructured surface, with a distinctive texture and a soft sense of touch.	**Perla 2.2 (Kvadrat).** 100 % wool. Made with double threads, and has a very coarse surface and texture. The structure gives a clear visual oversized pattern.

Note: In this table, the textiles range from typical hospital upholstery as Material A, and a coarse woollen upholstery as Material E. When presented for the patients, changing the numbers of the material samples randomised this range.

Finally, the patients were asked about their experience of the interior design in general in order to evaluate if they were satisfied with the existing interior, or if the had requests for improvements. After the interviews the data was divided into a quantitative and a qualitative strand, according to the mixed method strategy.

Results

The results of the mixed-method study will be presented with the quantitative data set first in order to construe the general picture. Subsequently, the qualitative statements will be presented to evaluate the stated preferences.

Quantitative results

Furniture

In the table below, the quantitative results on the preferences for furniture is presented.

Table 3: Patients' preference for furniture

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	Total group of patients	
	n	(%)
Chair 1	24	(55,8)
Chair 2	8	(18,6)
Chair 3	3	(7,0)
Chair 4	4	(9,3)
Chair 5	4	(9,3)

As the results indicate (table 3), the patients' furniture preferences are diverse, although the majority prefer chair 1. From this preferred chair, the popularity drops as the chair's home-like associations and the amount of textiles increase. This preference for the traditional hospital armchair is generally interesting, as it conflicts with the existing literature, where patients' request more home-like interiors (Horsburgh Jr, 1995; Lawson, Phiri and Wells-Thorpe, 2003), and this will be further unfolded through the qualitative results and the discussion section.

During the interview, the patients were also asked about their impressions of the general interior design, and here 79 % of the patients expressed an overall satisfaction regarding the existing interior, while 21 % requested improvements. Dividing the participants in sub-groups depending on the interior design satisfaction provides an interesting view on the preference diversity.

Table 4. Preferences for furniture depending on interior design satisfaction.

	General interior design			
	Satisfied		*Request improvements*	
	n	(%)	*n*	(%)
Chair 1	23	(67,6)	1	(11,1)
Chair 2	6	(17,6)	2	(22,2)
Chair 3	1	(2,9)	2	(22,2)
Chair 4	2	(5,9)	2	(22,2)
Chair 5	2	(5,9)	2	(22,2)

Although the typical hospital chair (Chair 1) may be the dominating preference for the patients, who are satisfied with the existing interior, the same chair is the least preferred by the patients' who are requesting improvements. The home-like, textile-based chairs (Chair 3-5) are instead the main preference for the 21% of the patients, who also have a preference for improved hospital interiors. This group furthermore corresponds to the literature, where patients request more home-like interiors, and for these change-oriented patients the link between preferences for home-like interiors and a preference for textile-based furniture and materials may be suggested. The general high degree of interior design satisfaction is also an interesting perspective in this study, and the patients' reason for this satisfaction, will be further unfolded through the qualitative results and the discussion.

Textile materials

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In the same structure as with the chairs, the participants' preferences for textile materials are here presented.

Table 5: Patients' preference for textile materials

	Total group of patients	
	n	(%)
Mat. A	12	(27,9)
Mat. B	11	(25,6)
Mat. C	14	(32,6)
Mat. D	3	(7,0)
Mat. E	3	(7,0)

The results on the patients' preference for textile materials generally indicate an overall preference for traditional woven textiles (table 5), with a smooth and even texture (Mat B and Mat C), but also the plastic coated fabric (Mat A) is amongst the preferred materials. The materials with a coarse textile structure (Mat D and Mat E) were considered least popular.

Table 6. Preferences for materials depending on interior design satisfaction.

	General interior design			
	Satisfied		*Request improvements*	
	n	(%)	*n*	(%)
Mat. A	11	(32,4)	1	(11,1)
Mat. B	8	(23,5)	3	(33,3)
Mat. C	10	(29,4)	4	(44,4)
Mat. D	2	(5,9)	1	(11,1)
Mat. E	3	(8,8)	0	-

As with the preference for furniture (table 3), there are a diverse variety of preferences for materials, and this variety is becoming more profound, when the patients are divided in regards to their interior design satisfaction. The patients who are satisfied have a remarkably stronger preference for the plastic material (Mat A), while the patients who are requesting improvements prefer the woollen textiles (Mat C).

Quantitative results – summary

In this pilot-study, the quantitative results highlight two interesting findings. First of all that the link between preferences for more accommodating, home-like environments and the preference for textile-based furniture and materials can be established for a smaller group of participants (21 %). Secondly, that a large group of patients (79 %) were satisfied with the existing interior, and had a preference for the traditional hospital furniture and materials. Conflicting with existing literature, this finding is particular interesting in regards to this study on hospital interior design and textiles, but also in regards to future studies on patients' preferences for hospital design. This aspect, will thus be further unfolded through the qualitative results and the discussion section.

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Qualitative results

The quantitative results have provided an overview of the patients' stated preferences, but has also indicated certain diversity. Through the next two sections, this will be unfolded by relating to the patients who are *'Requesting improved interiors'*; and the patients who are '*Satisfied with the existing interior*'.

Requesting improved interiors

In this study, the group of respondents who requested improved interiors also had a strong preference for home-like furniture and woollen textile materials, and as they correspond to existing literature, their concerns regarding furniture and materials are essential to address. When asked why they had chosen the textile-based objects, the primary response emphasised that the new types of furniture and the woollen textiles would make the hospital more cosy and home-like, and that the furniture would be more comfortable to sit in for a longer period of time.

> *"It would be nice to have more colours, more cosiness, natural materials and such. Maybe something like a lounge, with a cosy couch instead [of the current chairs]"* (Female, 25-39)

The specific material qualities of the furniture or the textiles, however, were most often not emphasised directly by the patients, and the aesthetic dimensions seemed difficult for the patients to articulate. Still this group of patients were interested in changing the current experience of the hospital environment, although they found it difficult to verbally express. The patients' preferences and interior design concerns fundamentally emphasise the importance of a less dull and institutional environment, where textile materials were found as a particular preference.

Satisfied with the existing interior

The group of patients who were satisfied with the existing interior also had a preference for the traditional hospital furniture and material, and although this evidently may relate to an actual preference, the qualitative part of the interview indicated that their preference in most cases were linked to their expectations rather than being a profound preference.

> *"I think it [the interior] is appropriate. It is fine. A table and a chair that is all you need"* (Male, 25-39)

The patients expressed that they found the interior appropriate, but indicated that they had no expectations or concerns regarding the appearance of the interior or the furniture. Some of the patients even explained that the hospital should not be luxurious facility, as they considered some of the comfortable home-like chairs. The furniture should just be comfortable to sit in, and as it was a hospital premises they expected a traditional hospital interior. Based on this perspective, the

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profound interior satisfaction may therefore be related to a low degree of expectations towards the hospital environment.

Discussion

The overall purpose of this study was to explore if the patients' preference for home-like interiors could be linked to a preference for textile-based furniture and materials. The quantitative results indicate that this may be the case, although it only constitutes 21% of the respondents. Furthermore the study found that the patients' preferences were closely linked to their expectations and that this could explain the preference for the traditional hospital furniture and materials. Concerned with this expectation-controlled preference, Bate and Robert (2007) argue in regards to experience-based hospital design that it is no longer sufficient to meet the patients' expectations but to exceed them (Bate and Robert, 2007). If the patients' baseline expectation is low, this will affect their stated satisfaction, and as is shown in this study also their preference for interior design objects.

Although it is only a smaller part of the respondents who in this pilot study prefer textiles and textile-based furniture, they are supported by literature and architectural theory. In an interview study by Caspari, Eriksson and Nåden (2011), a range of 'aesthetic experts' (artists, architects, designers, etc.) emphasised that the physical environment should be accommodating and that furniture of cold materials are not preferred from an aesthetic point of view (Caspari, Eriksson and Nåden, 2011).

Concerned with this diversity, this study highlights an interesting conflict in regards to preferences studies and patient participation. If the patients stated preference should be acknowledged, the hospital interior should remain as it is today, and if the 'experts' and the critical patients should be acknowledged, the home-like environment should constitute future hospitals. This perspective generally challenges the use of preferences studies, and it should be considered if the method could be strengthen in combination with design-related methods. In a study by Leather *et al* (2003), a re-designed waiting area was compared to a traditional waiting area, and here the patients were experiencing a greater satisfaction in the re-designed facility. The same affect would possible occur in a study on interior textiles, if the patients were presented with real physical changes in the hospital interior, and not just pictures of furniture and material samples?

Preference studies may provide initial knowledge on the patients' concerns regarding certain design aspects, but it seems difficult to explore design changes and potentials based solely on preference studies. New approaches could thus include more focus on the patients' experiences rather than their preferences, and studies could thus benefit from full-scale mock-ups as in the study by Leather *et al* (2003). This would evidently change the patients' experience, and evaluating design-based studies like these would provide new insights on the potential of interior design improvements.

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Conclusion

This pilot-study aimed to explore if the patients' preference for home-like interiors could be linked to a preference for textiles and textile-based furniture. For 21% of the patients this link could be made, but the large group of patients, who were satisfied with the existing interior and preferred the traditional hospital furniture, is a particular interesting finding in this study. As this contradicted with existing literature, reasons for this was found in the qualitative interviews, and their preferences were thereby linked to low baseline expectations. On the basis of this study, new approaches to conducting additional studies on materials and hospital design have been suggested, emphasising the need for design-based methods and full-scale mock-up studies. With the experiences from this pilot study new research studies may be developed for testing and exploring the potential of interior design and materials in regards to healing architecture.

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References

BATE, P. and ROBERT, G.B. (2007). *Bringing user experience to healthcare improvement: the concepts, methods and practices of experience-based design*. Oxford: Radcliffe.

BÖHME, G. (1993). Atmosphere as the fundamental concept of a new aesthetics. *Thesis eleven*, **36** (1), 113-126.

CASPARI, S., ERIKSSON, K. and NÅDEN, D. (2011). The importance of aesthetic surroundings: a study interviewing experts within different aesthetic fields. *Scandinavian Journal of Caring Sciences*, **25** (1), 134-142.

DOUGLAS, C.H. and DOUGLAS, M.R. (2004). Patient-friendly hospital environments: exploring the patients' perspective. *Health Expectations*, **7** (1), 61-73.

FRANDSEN, A.K., MULLINS, M., RYHL, C., FOLMER, M.B., FICH, L.B., ØIEN, T.B. and SØRENSEN, N.L., 2009. Healing Architecture. Report. [online]. Last accessed 20 February 2015 at: http://vbn.aau.dk, Institut for Arkitektur og Medieteknologi, Aalborg Universitet.

HORSBURGH JR, C.R. (1995). Healing by design. *New England Journal of Medicine*, **333** (11), 735-740.

LAWSON, B., PHIRI, M. and WELLS-THORPE, J. (2003). The Architectural Healthcare Environment and its Effects on Patient Health Outcomes. NHS Estates. Report. [online]. Last accessed 20 February 2015 at: http://www.wales.nhs.uk.

LEATHER, P., BEALE, D., SANTOS, A., WATTS, J. and LEE, L. (2003). Outcomes of environmental appraisal of different hospital waiting areas. *Environment and Behavior*, **35** (6), 842-869.

MOGENSEN, J.E., FISKER, A.M. and POULSEN, S.B. (2014). Interior Textiles and the Concept of Atmospheres - A Case Study on the Architectural Potential of Textiles in Danish Hospital Interiors. *14th Biennial Symposium Proceedings: New Directions: Examining the Past, Creating the Future 2014*, Textile Society of America.

MOGENSEN, J., JORGENSEN, P. and POULSEN, S.B. (2014). Design Innovations and Implementation Challenges - A Case of Smart Textiles in Future Hospital Interiors. *DS 77: Proceedings of the DESIGN 2014 13th International Design Conference 2014*, 935-945.

ULRICH, R.S., ZIMRING, C., ZHU, X., DUBOSE, J., SEO, H., CHOI, Y., QUAN, X. and JOSEPH, A. (2008). A review of the research literature on evidence-based healthcare design. *Health Environments Research & Design Journal*, **1** (3), 61-125.

ZUMTHOR, P. (2006). *Atmospheres: architectural environments - surrounding objects*. Basel: Birkhäuser.

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PAPER F

Home-like hospital environments – How furniture and materials in a refurbished hospital dayroom influence the patient experience

Jeppe Emil Mogensen, Anna Marie Fisker & Søren Bolvig Poulsen

Abstract:

Research in the field of healing architecture has increased significantly, but knowledge on how design elements of furniture and materials influences the patients' experience is still lacking. The intimate scale of interiors affects the perception of the space extensively, and as most contemporary hospitals are criticised of being too institutional, the potential of more accommodating interiors in hospital dayrooms are considered immense.
Concerned with this potential, and inspired by research on 'home-like environments', this paper presents the results from a qualitative pilot-study, observing and interviewing patients and staff in a refurbished dayroom at the Nephrology Department at a Danish hospital. By installing home-like furniture and materials as basic design changes, the interior of the dayroom was altered, and the purpose of this pilot-study was to explore the patients' experience in this refurbished hospital dayroom, and thereby examine the potential of home-like atmospheres in hospital environments.
The summative evaluation of the study indicates that the patients experience the atmosphere more accommodating in the refurbished interior, and the patients express that they use the dayroom more often. The new home-like furniture and materials are emphasised as elements that improve the environmental experience. Based on these preliminary findings, the pilot-study accentuates the importance of interior design at hospitals, and highlights the relevance of focusing on the small, sensuous scale of the otherwise large-scale hospital buildings. From this perspective, future interior design studies are suggested to focus on the patient outcome and the long-term effects of improving the design of hospital interiors.

Keywords:
Health-care design, furniture, materials, architecture, interior design, patient experiences

Introduction

The Danish health care sector is undergoing a significant modification, and the same tendencies are observed throughout Europe and the U.S. New hospitals are under construction, and the physical environment and its effect on the patients' healing process have gradually been recognised (Frandsen, Ryhl, Folmer, Fich, Øien, Sørensen & Mullins, 2009). While most existing hospitals, constructed in the 1960s and 1970s, were designed as rational machines for treatment (Dirckinck-Holmfeld, Hornung, Damgaard-Sørensen & Heslet, 2007), the emerging design concept *healing architecture* has nationally and internationally re-defined a vision for future hospitals, envisaging that the patients healing process is associated with a stimulating and accommodating physical environment (Bromley, 2012; Frandsen et al., 2009; Ulrich, Zimring, Zhu, DuBose, Seo, Choi, Quan & Joseph, 2008). It is essentially not the architecture or design alone that heal the patient, but research on design aspects of light, acoustics, daylight, art, among others, concordantly demonstrate that there is a link between hospital design and improved healing processes (Dirckinck-Holmfeld et al. 2007, Ulrich et al. 2008).

However, despite the still increasing research in hospital design, knowledge on how specific aspects of interior design, in terms of furniture and materials, affect the patients' experience is still rather limited (Douglas & Douglas, 2004).
In patient reports and interview studies, patients are requesting more 'home-like' interiors (Caspari, Nåden, & Eriksson, 2007; Danish Patients, 2009; Douglas & Douglas, 2004; Lawson, Phiri, & Wells-Thorpe, 2003), and Horsburgh suggested back in 1995, that *"making the hospital more homelike and less impersonal is an important way to indicate that the focus of the hospital is on the individual patient"* (Horsburgh, 1995, p. 738).
From a design perspective, this home-like experience links closely to the use of furniture and materials that generate the room atmosphere (Böhme, 1993; Böhme, 2013; Zumthor, 2006), and facilitate the potential activities and behaviours in the room (Gulløv & Højlund, 2005). However, so far these interior design aspects have not been addressed in research studies, and relative to the patients' experience of the physical hospital surroundings, it is peculiar that these essential interior design elements have not received more attention in hospital design research.

Concerned with this lack of research, which will be further defined in the following theoretical framing, this paper will present the results from a recent pilot-study, where a dayroom at a Danish hospital was refurbished with new furniture and materials to provide a more home-like atmosphere. The purpose of the study has thus been to explore the patients' experiences in this refurbished hospital dayroom, and examine the potential of home-like atmospheres in hospital environments.

The potential of home-like atmospheres in hospital environments

Before we describe and present the basic design changes and the patients' experience of the refurbished dayroom, the term 'home-like' will be defined in order to establish a theoretical framework for the study.

Fig. 1. Picture from a dayroom arrangement at a recently built Danish Hospital, where the hard surface materials, plastic upholstery, etc., imbue an institutional atmosphere. (Hospital Vendsyssel, Hjørring)

The picture above (fig. 1), is from a recently built Danish hospital, and illustrates how the physical environment in modern hospitals still imbues a rather institutional atmosphere, despite the increased focus on healing architecture. The 'home-like hospital', which patients generally request (Caspari, Nåden & Eriksson, 2007; Danish Patients, 2009; Douglas & Douglas, 2004; Lawson et al., 2003) is thus still a contrast to the current institutional environment (Jonsson, Östlund, Warell, & Dalholm Hornyánszky, 2014). 'Home' is generally associated with something quite different than the current hospital institution. Our home is a very personal space, where we have defined our private base by adding a personal touch, and our home is thereby often considered a physical portrayal of ourselves (Sjørslev, 2007; Winther, 2006). These personal aspects of our home is obviously difficult – if not impossible – to take into account when designing new large hospitals, where thousands of different patients are hospitalised, and often in shorter periods of time. However, there are elements of this home-like feeling that are possible to reproduce in public places like the hospital.

The Danish anthropologist Ida Winther, emphasise that home and home-like environments can be explained on different levels, ranging from the physical home, where we live, to the 'feeling of home', which may also be experienced in other places. The feeling of home thus becomes a symbol of privacy, comfort, security,

family life and happiness (Lewicka 2011), and being at home is inherently a positive experiential state (Jonsson et al. 2014). The concept of home is thus a cultural and ideological construction shared in society, and although the idea of home most often is related strongly to our private house, the feeling of home is in modern society changing to become a mobile sense of atmospheres or ambiances (Winther 2006). The feeling of home can be carried along, and we can feel at home in a hotel room, at our office or even in some carefully designed public spaces (ibid). To experience this home-like feeling, Winther (2006) emphasise the importance of being surrounded by recognisable associations, which may be other persons, activities or physical objects.
However, when hospitalised, many different persons inevitably surround the patients, and the routines and predefined activities are also very different from a normal day at home. Even the physical objects, and the interior of the hospital, are today imbuing an often typical institutional atmosphere (fig. 1), which is far from the home-like, comfortable and accommodating surroundings that patients prefer and request (Caspari, Nåden & Eriksson, 2007; Danish Patients, 2009; Douglas & Douglas, 2004; Lawson et al., 2003). From a design perspective, an increased use of recognisable and symbolic objects, furniture and materials could thus potentially improve the physical surrounding of hospitals, by supporting and facilitating a more home-like experience.

Today, the hospital furniture and materials are predominantly selected on the basis of functional considerations, which characterise the aesthetic appearance of the general interior (as illustrated in fig. 1). The shape of the chairs is promoting a correct posture, and although this essentially is relevant for most patients, this recognisable chair typology is defining the room atmosphere by their visual appearance. Even the plastic upholstery (polyurethane), chosen for its efficient cleaning ability, promotes this institutional feeling. The furniture of contemporary hospitals is thus regarded as primarily functional instruments for seating, while the sensuous, tactile, emotional and experience-based dimension of the interior objects seems to be neglected.

To change this institutional experience of the hospital interior and to support the experience of more home-like environments, there is a particular need to focus on the furniture and materials of the hospital interior.

Past research in home-like hospital environments

Past research studies on patients' experiences of hospital design have addressed the potential of home-like interiors, but very few have been found that address the use of furniture and materials to improve the design experience.
In a qualitative study by Douglas and Douglas (2004), focus is directed on the patients' general experience of the physical environment, and the patients generally state that they request more home-like environments. However, although the objective of the study was to improve the built environment of future hospitals, this request was only related to functional aspects of increased privacy, having visitors, and being able to control the TV. The authors ascertain that the perception of the built environment is influenced to a large extent by the general atmosphere, but the aesthetic dimensions that affect this atmosphere are not further articulated in the paper.
A related study by Shin, Maxwell and Eshelman (2004), addressed Mothers' perception of *'hominess'* in maternity wards. Hominess is here defined as the spatial quality that makes the atmosphere feel residential, and based on drawings, where

different design elements are altered, the participants evaluate the degree of hominess and state their preference. The study concludes that increased perception of hominess is correlated to increased preference, but of the seven different design elements that were altered in the drawings, none of them addressed the use of furniture or materials.

One of the few studies that address furniture in hospitals is the study by Caspari, Eriksson and Nåden (2010). The study is concerned with the importance of aesthetic surroundings of hospitals, and addresses this issue by interviewing experts within different aesthetic fields (interior design, architecture, art, etc.). The experts use the term home-like to express their request for improved interior atmospheres, and emphasise that cold, hard materials like plastic and steel is not suitable for hospital furniture. The furnishing of contemporary hospitals is described as *'eclectic storage items'* (Caspari, Eriksson & Nåden, p. 138), and the experts prefer materials like textiles in bright, happy colours instead. The study thus addresses and emphasise the importance of home-like hospital interiors that present a harmonious and pleasant atmosphere (Caspari, Eriksson & Nåden, 2010), but the study does not relate these findings to observations of patients' experiences. The author's define the study as one of the first to address the aesthetic experience of hospital interiors (Caspari, Eriksson & Nåden, 2010), and a good theoretical framework for future design-based studies is established.

A few other studies have in recent years addressed focus on hospital furniture and its effect on patient outcomes (Malone & Dellinger, 2011; Salonen et al. 2013), but generally these studies have a tendency to focus on the functional and ergonomic aspects of furniture design. Seeking to provide an evidence-based design furniture checklist for facilitating the best furniture purchases, Malone and Dellinger (2011) list 35 variables of furniture design, where only 2 of them relate to the patients emotional experience of the furniture (1; 'materials are suggested to link to nature', and 2; 'the appearance should be attractive and non-institutional'). These statements are only moderately supported by the included review of existing literature, and the rest of the 35 design variables are concerned with mere functional aspects of cleaning ability and ergonomic features. The review study by Salonen et al. (2013), address the physical characteristics of the indoor environment that affect health and well-being in healthcare facilities, but furniture is again solely related to ergonomic aspects that should improve performance and staff satisfaction.

Studies of home-like atmospheres in hospital interiors still haven't addressed the use of furniture and materials through empirical inquiries exploring the patients' experiences, although research on the use of furniture in nursing homes suggest there is a strong potential.
Johnson et al. (2014) explored the relationship between people and furniture to understand how the physical environment affected the elderly residents in nursing homes, and found that the material artefacts were important in the 'home-making' process, and that the interior objects made a deeper impact than we often think. The residents were most concerned with the interior of their private rooms, as they here could bring their own furniture, which was often associated with memories and emotional factors. In shared spaces, the residents often described the furniture as too heavy and clumsy, and while the staffs were concerned with the maintenance of the furniture, the residents did not mention this issue. In Johnson's study the furniture of the private and shared spaces are thus perceived differently, and the residents clearly

perceive the border between their private room and the shared space. A related study by Morgan-Brown et al. (2012), however, found that when the interior design of a nursing home was changed into a more home-like facility, the spontaneous interactions was increased, and the residents spend more time in the communal areas. The recent study by Morgan-Brown et al. (2012), thus confirm an older study by Zavotka and Teaford (1997), who also found that shared rooms at a nursing home were perceived more personal and more time was spend there, if the furnishing was associated with the residents' previous homes (Zavotka & Teaford, 1997).

Past research on home-like interiors in nursing homes generally suggest that a greater sense of calmness and a feeling of comfort and safety could be supported if furniture was associated with homes rather than institutions. Related to the hospital environment, home-like furniture and materials could probably promote the atmosphere in this context as well, providing a felling of safety, psychological comfort and general well-being (Lewicka, 2011; Winther, 2006).

Being at home is associative with a positive, relaxing experience, both physically and mentally, and furniture is important for this experience as physical objects with recognisable, symbolic associations (Winther, 2006; Johnson et al., 2014). However, there has been found no previous design studies that have addressed this potential of furniture and materials in hospital interiors. Existing research can provide the theoretical link between improved patient experiences and a home-like hospital interior, but empirical studies on patients' experiences are considered needed to contextualise these theoretical observations and relate them to specific interior design aspects.
Having established this theoretical framework, underlining the importance and potential of home-like hospital environments, the paper will relate to a pilot-study, where a hospital dayroom was refurbished to provide a more home-like atmosphere, and the patients' experience of the dayroom has been explored.

Case

The study of the patients' experience of the home-like hospital environment is designed as a full-scale mock-up study at the Nephrology department at Odense University Hospital. Through a three-week period, the dayroom was refurbished with particularly focus on defining a more home-like atmosphere, and through qualitative studies, the patients' experience was analysed. The department attend to diagnostics, treatment and nursing of patients with acute and chronic renal failures and have 19 beds at disposal. The patients in this ward constitute a broad mix of age, length of hospitalisation (from hours to weeks) and mobility (bed bound patients as well as patients who are up and walking). The dayroom is a separate room, where the patients can go by them selves during their time at the department. In periods, the room is frequently in use for family visits, watching television, reading magazines or social conversations.

The existing dayroom interior

Fig. 2. Existing dayroom interior at the Nephrology Department, Odense University Hospital.

The existing dayroom was an oblong room, with a notable high window at the end of the room. A small dresser and a TV were placed next to the window, and the rest of the furniture consisted of wood framed armchairs with dark red, plastic upholstery. The furniture was placed along the walls, and besides the furniture an exercise bike, a fridge and a microwave oven constituted the room interior.

Prior to the refurbishment of the dayroom, designers at the Health Innovation Centre of Southern Denmark made an exploratory user-study concerning the existing dayroom interior. This study included focus group interviews with staff, patient interviews with 4 patients, and observations (Kjærsig & Linaa, 2015). Focus in the user-study was directed at the experience of the physical environment, and the study summarised that the patients experienced the existing dayroom as a clinical and institutional setting. Observations indicated that the room rarely was in use, and the

patients expressed that they did not find any motivation for visiting the dayroom. Most often, it was only readmission patients, who while waiting for a hospital bed were occupying the dayroom. The bike, refrigerator or micro oven were not used either, and the patients found that the room was too small for longer occupation. It was generally perceived as a boring and uninspiring interior, and the patients expressed a wish for a more home-like atmosphere and setting (Kjærsig & Linaa, 2015).

Methods

Design changes

The refurbishment of the dayroom was partly based on the theoretical framework, which described the potential of providing a more home-like setting in the hospital environment, and secondly on the patients' experiences and concerns regarding the existing dayroom (Kjærsig & Linaa, 2015). Architects from the Health Innovation Centre of Southern Denmark, in cooperation with the authors of this paper, defined the specific design changes, which can be summarised in two main areas. First of all, a range of home related objects and accessories were assigned to the dayroom, including artworks, books, bookshelves, candles (electric) and flowers, and the objects that associated the hospital, like patient information folders, have been removed. According to the literature (Winther, 2006; Jonsson et al., 2014), the installed home-like references are considered recognisable objects that the patients' potentially will associate with traditional Danish homes.
Secondly, the furniture and furniture materials that earlier expressed an institutional atmosphere in the dayroom were replaced by home-like furniture upholstered with woollen textiles (Design: HAY, 'about a chair', Upholstery: Kvadrat A/S, 'Hallingdal 65', Wool). The furniture was chosen to reflect current cultural trends in Danish residential interior design, and the harmonious colour scheme of cooler colours of green and blue were selected to provide a calming and relaxing environment (Salonen et al., 2013). Newly restored wooden lounge chairs were also installed, and arranged with soft cushions, in the same colour scheme, to relate to a familiar home-like environment. Textiles were also used to frame the large window as a large soft curtain (See fig. 3).
As it is evident from the design changes, the intention with the design solution was not to propose innovative, state-of-the-art interiors for hospitals, but rather to take simple, basic interior designs and apply them to the hospital environment. With these common design interventions, the contrast to the traditional hospital made a clear distinction and highlighted the potentials of improving the hospital interior design.

Fig. 3. Refurbished dayroom at the Nephrology Department, Odense University Hospital.

Data collection

To collect data on the patients' experience of the refurbished hospital dayroom, and in order to clarify and unfold their perspective, triangulation of three qualitative methods were applied. The evaluation of the patients' experience was thus based on observations, patient interviews and staff interviews, combining objective as well as subjective outcomes.

Observations: The observations were performed by the first author of the paper, and constituted the first evaluative study, where the patients' actions and behaviour in the hospital dayroom were observed. The observer was situated in the room for two consecutive days (30.3.2015, 08.30 – 17.30 and 31.03.2015, 08.30 – 14.30), representing a patient, while registering the other patients' doings. The observation was kept open-ended, and focused particularly on the themes: 'activities' – *what was the patients doing?*; 'social interaction' – *did the patients interact with each other or visitors?*; and 'interaction with furniture and objects' – *how did the patients' use the furniture and new home-like objects*?

The hospitalised patients were only visiting the dayroom for shorter periods of time, and were individually not aware or informed of the observers' role. The observations thereby provided an immediate objective impression of the patients' behaviour, which was used to inform and support the evaluation and interpretation of the following patients- and staff-interviews.

Patient interviews: In consultation with the staff, four patients were selected to participate in in-depth interviews regarding their experience of the hospital dayroom. The patients were selected in regards to their course of illness and mobility, as the interview should not influence their medical process of recovery. Two males (both age 56) and two females (age 56 and 70), participated individually in a semi-structured interview. The interviews were conducted in the dayroom with duration of 5-15 minutes, depending on the patients' course of disease. Focus was directed on their hospital experience, with particularly emphasis on their experience and use of the refurbished dayroom. The themes of the interview included: 1) background information about personal data and hospitalisation experiences; 2) their perception and concerns regarding hospital design in general; 3) their experiences of the refurbished hospital dayroom; 4) and finally their perspectives regarding design of future hospitals. As the interviews did not relate to the patients course of disease nor included any medical data, ethical approval was not found relevant for this study.

Staff interviews: Subsequent to the patient interviews, the charge nurse was interviewed in order to qualify the patient statements. The nurse was not informed about the results of the observations or patient interviews, and her prolonged dialogues, interactions and professional observations of the patients was thus used to confirm the researcher's observations and evaluations. The interview was semi-structured, and based on the themes: 1) the patients' experience and behaviour; 2) positive or negative response to the refurbishment; 3) good and bad experiences; 4) challenges.

Data from the observations and interviews was subsequently transcribed and analysed for themes using the data software nVivo. The evaluation of the data was based on Steinar Kvales definition of hermeneutic interpretation of qualitative data (Kvale, 1997). The transcribed observations and interviews were first read to generate a general meaning of the data, and based on this meaning different themes were developed in a continuously process between the parts and entirety of the data (ibid). The themes were thus reflected in the general meaning of the transcribed data, and when triangulating the data from observations, patient interviews and staff interviews, the themes were furthermore related to the three different data sets.

Results

The aim of the study was to explore the patients' experience of the home-like hospital interior, and to examine the immediate potential of home-like atmospheres in hospital environments. According to the method of hermeneutic interpretation (Kvale, 1997), the results have been summarised in three overall themes that combines data from the observations, patient– and staff interviews. The themes were defined as: 1) *'The perceived interior atmosphere*'; 2) '*Materials as home-like references'*; and 3) *'Patient behaviour'*.

The perceived interior atmosphere

The patients generally experienced the refurbished hospital dayroom as a comfortable environment, and all the patients were referring to the interior as a home-like atmosphere. The dayroom was perceived as a warm, welcoming 'living room', which the patients associated with a feeling of home. The patients explained through the interviews that the dayroom was remarkably different from the rest of the hospital environment, and that the room was experienced as an oasis of peace and quiet, imbuing a relaxing comfort.

"It [the interior] seems very home-like and cosy, and it is like entering a quiet nook - an enclosed hideout, where you can experience a little peace and security" (Female patient, 56 years old)

Although the refurbished facility was unexpected, none of the patients considered the room as inappropriate or strange for the hospital. Instead, they adapted to the new settings and enjoyed the possibility to withdraw from the traditional hospital environment. One of the patients, who had been at the department several times before, related the cosy experience to the use of new furniture and materials as well as the arrangement of chairs in smaller groups of seating: *"Earlier there was a large dining table and then some chairs - that was all. But now there are these small lounges and cosy corners, which is very nice"* (Female, 70).
The staff interview confirmed that the patients generally perceived the refurbished dayroom in a positive way, and none of the hospitalised patients' had expressed a negative concern regarding the new interior during the pilot-study.
Also the sounds of the room were perceived differently. One of the patients emphasised that the acoustics of the room defined a rather relaxing atmosphere, and the noise from the hallways were reduced remarkably: *"Almost like if there was a carpet installed in the room."* (Female, 56). The interior of the new dayroom was thus significantly improving the patients' experience: *"You feel like at home. It is better than the traditional hospital, with the white walls and white coats."* (Male, 56).

Materials as home-like references

As described in the previous section, the atmosphere of the new dayroom was experienced as home-like and accommodating, giving the impression that you were sitting in a living room. Throughout the interviews, the patients emphasised how the objects and materials in the room contributed to this experience. The wallpaper that

resembled bookshelves, the flowers, the books and artwork on the walls were highlighted as certain artefacts to imbue the recognisable familiar atmosphere. *"I like the bookshelves that doesn't take up much space, but they provide cosiness and a warm atmosphere, when you sit here in the evening."* (Female, 56).
Also, the textiles were described as materials that promoted the home-like and relaxing experience. The long floor-to-ceiling curtain that covered the back wall and framed the view through the tall window; the wool-based lounge furniture and the cushions in the chairs, reflected the accommodating, welcoming environments associated with homes. Textiles were thus giving a range of tactile references, and as the nurse emphasised *"you would never choose a chair or a sofa in plastic upholstery for your home, as we normally do here, so it provides a different experience. You will feel more like home in a room with textiles."* (Nurse).
Through the observations it was also evident that the patients interacted customary with the textile objects in the room. The cushions were adjusted for appropriate seating, legs were crossed and the seating position was observed to be more laid-back, than usually observed in a hospital setting. The patients confirmed this observation, and expressed through the interviews that the soft furniture was more comfortable and relaxing than traditional hospital chairs. Also the wool was accentuated, as a particularly needed contrast to the traditional hospital materials:
"It [the upholstery] is extremely pleasurable, when it is so 'warm' and structured. It is a pleasure for the body to be met by [a material like this]. Normally, we are sitting in bed linen the entire day sliding around, but when your body hurts it is comfortable to sit in materials like these instead." (Female, 56).

Patient behaviour

Based on the observations and interviews, indications were found that the patients used the refurbished dayroom in another way than they used to. Previously, the dayroom was mainly used as a waiting area for readmission patients, but in the home-like interior, the patients were also motivated to visit the dayroom for a cup of coffee or for reading a magazine. One of the patients, who were suffering from a chronic disease had been hospitalised at the ward many times, but had never used the dayroom before. The refurbished, home-like environment, however, gave her a motivation to visit the dayroom, and she sought the opportunity to visit the room daily during her hospitalisation. *"I never used it [the dayroom] before, […], but now I really enjoy spending time here. To get up, and get away from the hospital bed."* (Female, 56). The nurse, who has experienced that the dayroom is used more extensively for social intercourse, confirms this observation and patient statements, and remarks that the refurbishment also changed the way the staff behave. *"It has made a certain impact on both patients and staff that you have a good experience by entering the room […]. When our dayroom had its original design with hospital related objects, you did not notice when a used medicine cup, thermometer or other medical equipment was lying around. But now you are motivated to keep the appearance and to clean up in the room. And you are proud to ask the patients, if they would like to wait or visit the dayroom."* (Nurse).

During the observation, the patients' more relaxed positions and postures also indicated a certain behavioural effect. One of the patients took his shoes off to take a nap on the couch, and another patient was lying on the couch watching television.

Although these behavioural patterns and activities are usual for homes or domestic settings, they remain rare in a public hospital dayroom. The change of the interior design, however, seemed to affect the patients' use of the dayroom as well as their behaviour.

Discussion

This explorative pilot-study has provided knowledge on how patients perceive and experience a more home-like hospital interior, and the potential of interior design improvements has been exemplified. The patients experience the refurbished dayroom accommodating, and characterise it as a harmonic space, based on familiar, recognisable objects and materials that are associated with home-like environments. In environmental psychology, this connection between positive experiences and familiar environments are related to an unconscious human need to have our existing 'knowledge structures' confirmed (Purcell & Nasar, 1995). Our experience of space consists of repeated encounters with different types of environments, and we construct a mental representation of the regularities in these different categories of spaces. When a new space fits within our existing knowledge structure, the experience is associated with a 'warm glow' of familiarity (Purcell & Nasar, 1995). The theory, however, also suggests that small discrepancies in knowledge structures cause an increase in cognitive activity, and produce liking and preference for the objects (Purcell & Nasar, 1995). This is explained by a basic human curiosity, as we like to be surprised and to learn more about different environments (Berlyne, 1971; Cold, Kolstad, & Larssæther, 1998). The fact that the home-like environment is actually situated at the hospital may have caused this increased attention and attraction to the dayroom. In the pilot-study, the dayroom was intended to provide a home-like atmosphere, and the results indicate that the patients' used this refurbished dayroom more than usual. In studies at nursing homes, the residents' emotional well-being were also found to be enhanced by physical environments that provide similar perceptions as their previous homes, and more time was spent in the dayrooms if the level of furnishing formality was similar to their previous home (Jonsson, Östlund, Warell, & Dalholm Hornyánszky, 2014; Morgan-Brown et al., 2012; Zavotka & Teaford, 1997).

From a patient perspective, the home-like environments could thus be regarded as a significant improvement of traditional hospital interiors. It should, however, be considered in which locations the potential of providing these accommodating settings are most relevant. In a previous Danish interview study by Lemche (2012), some patients expressed a preference for the traditional hospital interior. Although this study is not based on a refurbished mock-up study, it should be considered if the typological hospital environment might provide a certain degree of security for some patients? It is essentially a different kind of security than the kind associated with home, but for patients with a severe disease, the white hospital walls and the recognisable institutional atmosphere could be associated with professionalism and medical assistance to gain recovery. Emergency departments, operation rooms, etc., could thus constitute hospital environments, where the traditional, clinical hospital design could be preferred, while the wards, bedrooms and dayrooms are areas where the home-like surroundings, as in this study, could provide a positive patient experience.

The material influence on the home-like atmosphere

In this study one of the main design changes was the installation of new home-like furniture and materials. In architectural theory, the materials' importance for the perception and experience of space has long been acknowledged, but in the hospital context, the materials' influence on the patients' experience has been inadequately recognised. Today, it is predominantly the rational concerns that guide the interior design decisions, especially regarding the use of materials (Mogensen, Jorgensen, & Poulsen, 2014). As illustrated in the current hospital interiors (image 1 and 2), the hospital furniture is upholstered with plastic materials that are easy to clean and maintain, and although the hygiene in hospitals is essential, textiles with cleaning friendly coatings could potentially be used as alternatives (Mogensen et al., 2014; Mogensen, Jørgensen, & Thomsen, 2015).
Architectural theorist Juhani Pallasmaa (2001), who is very concerned with the tactile dimension of contemporary architecture, criticises this rational approach to the design of hospitals. Organised as factories, Pallasmaa argues that the hospitals are transforming the patients to objects of detached mechanical treatment. *"It is typical of our culture with its adulation of strength and performance that more attention is paid to the characteristics of the work environment than to the characteristics of the curing environment from the point of view of the patient and his cure"* (Pallasmaa, 2001 p . 218).

The potential of interior design changes is therefore also considered related to the use of more home-like materials in hospital interiors. The patients emphasise the materials contribution to the hospital atmosphere, and it is uncertain if the same degree of home-like experiences could be achieved by the use of plastic-coated upholsteries. Additional studies focusing particularly on the patients' material experience could provide valuable new insights to guide future hospital interior design. This pilot-study has provided the indications and foundations for proposing additional studies on this material potential.

Behavioural change

In this study the patients' behaviour in the refurbished dayroom was observed, and indications were found that the more home-like atmosphere also influenced their activities and use of the dayroom. Some of the patients confirmed through the interview that they used the dayroom more, because the accommodating atmosphere motivated them to visit the facility. This finding is particularly interesting in regards to patient mobility and potentially improved outcomes. An earlier study on older patients mobility during hospitalisation has shown that medical patients in average spend less than 45 minutes a day walking or standing. The rest of the time they spend in their bed (Brown, Redden, Flood, & Allman, 2009). For older adults, this low mobility is especially causing concern, as it is associated with adverse outcomes, including functional decline and need for nursing home placements, but also younger adults show a severe loss of muscle mass within 24 hours of supine position (Brown et al., 2009). The value of hospital environments that actually motivates the patients to get out of their beds are considerably immense in regards to healing processes and patient outcomes. If accommodating interior design surroundings could be an

incentive for the patients to gain their mobility faster, economic reasons for refurbishing the interiors are provided. Additional long-term studies on these aspects are considered fundamentally essential, and would be valuable to progress in regards to the construction of new hospitals.

Limitations of the study

The potential of improving the interior design of hospital dayrooms, has with this pilot-study been explored, and the home-like interior has been found to promote the patients' hospital experience. The more accommodating atmosphere in the dayroom even facilitated an increased use of the room, with potential benefits in regards to patients' mobility. However, the pilot-study is one of the first scientific studies to explore the patients' experiences in a more home-like hospital dayroom, and there are thus certain methodological limitations of the study. Four patients participated in the qualitative interviews, and it could be discussed whether more patients should have been included to provide a broader perspective. However, the four patients expressed the same general experience of the refurbished dayroom, and as the observations and staff interview with the charge nurse confirmed this perspective, the patients' statements were qualified through the triangulation of methods. The findings of the study was furthermore reflected in past research on the potential of home-like furniture in nursing homes (Jonsson et al. 2014, Morgan-Brown et al., 2012; Zavotka & Teaford 1997), and a larger sample size was thus not considered likely to provide a different perspective in the pilot-study.
However, additional research studies in larger scale are considered needed to further explore the patients' experiences and to document the potential outcomes related to the interior design improvements.
To ensure the possibility of triangulating the three qualitative methods, one person conducted the observations and interviews. The observer (first author of the paper) is educated architect and has experience in conducting user-studies on patients' experiences of hospital design, and although an additional researcher could have provided a relevant frame of reference, the fact that one person conducted both interviews and observations provided a solid consistency to the study. Again, the observations and general experience of the charge nurse was used as a reference for interpreting the interviews and observations.
The qualitative approach thus reflected the exploratory nature of the pilot-study, and the triangulation of three qualitative methods have provided a research design that could collect data on the patients' experience from a broad perspective. With the results of this exploratory pilot-study, a solid foundation for new design studies on home-like hospital interiors has been established.

Conclusion

This pilot-study explored how patients experience a more home-like hospital interior, and the potential of interior design improvements in hospital dayrooms has with this study been accentuated. The general preference for home-like hospital environments, as emphasised in earlier studies (Caspari, Nåden & Eriksson, 2007; Danish Patients, 2009; Douglas & Douglas, 2004; Lawson et al., 2003) was confirmed, and the basic design changes, using home-like furniture and materials, were highlighted as

contributors in facilitating the intended atmosphere. The patients have through observations and interviews shown and explained how they experience the room as a comfortable, relaxing and accommodating contrast to the traditional hospital environment. An essential finding relates to the patients more relaxed behaviour and increased use of the dayroom. By refurbishing the dayroom, the patients were motivated to visit the facility, and patients who never used the dayroom before, visited the new dayroom daily. If the patients' mobility can be stimulated by these interior design changes, the potential of home-like hospital interiors are immense. On the basis of this pilot study, additional studies should thus be initiated in order to explore the long-term effects and patient outcomes related to interior design improvements, and analyse the life-cycle costs and maintenance issues related to the use of home-like furniture and materials in the hospital. The relevance of new home-like interiors in hospitals has with this study been emphasised, and from this perspective it remain an important assignment for future interior designers to propose new design solutions for hospital interiors that can facilitate the patients' healing process and thus progress the design concept of healing architecture.

References

Berlyne, D. E. (1971). Aesthetics and psychobiology, Appleton-Century-Crofts, New York.

Böhme, G. (1993). Atmosphere as the fundamental concept of a new aesthetics. *Thesis Eleven, 36*(1), 113-126.

Böhme, G. (2013). Atmosphere as mindful physical presence in space. *Oase #91 - Building Atmosphere,* 21-32.

Bromley, E. (2012). Building patient-centeredness: Hospital design as an interpretive act. *Social Science & Medicine, 75*(6), 1057-66.

Brown, C. J., Redden, D. T., Flood, K. L., & Allman, R. M. (2009). The underrecognized epidemic of low mobility during hospitalization of older adults. *Journal of the American Geriatrics Society, 57*(9), 1660-1665.

Caspari, S., Nåden, D., & Eriksson, K. (2007). Why not ask the patient? an evaluation of the aesthetic surroundings in hospitals by patients. *Quality Management in Health Care, 16*(3), 280-292.

Caspari, S., Eriksson, K. & Nåden, D. (2010). The importance of aesthetic surroundings: a study interviewing experts within different aesthetic fields. *Scandinavian Journal of Caring Sciences,* vol. 25, no. 1, pp. 134-142.

Cold, B., Kolstad, A., & Larssæther, S. (1998). *Aesthetics, well-being and health: Abstracts on theoretical and empirical research within environmental aesthetics,* Norsk Form.

Danish Patients. (2009). *Fremtidens sygehusbyggeri - patienternes perspektiv [future hospital buildings - the patients' perspective]*. Available at: www.danskepatienter.dk (accessed 15.02.2015)

Dirckinck-Holmfeld, K., Hornung, P. M., Damgaard-Sørensen, H., & Heslet, L. (2007). *Sansernes hospital,* Arkitektens Forlag, Denmark.

Douglas, C. H., & Douglas, M. R. (2004). Patient-friendly hospital environments: Exploring the patients' perspective. *Health Expectations, 7*(1), 61-73.

Fottler, M. D., Ford, R. C., Roberts, V., Ford, E. W., & Spears Jr, J. D. (2000). Creating a healing environment: The importance of the service setting in the new consumer-oriented healthcare system. *Journal of Healthcare Management, 45*, 91-107.

Frandsen, A. K., Mullins, M., Ryhl, C., Folmer, M. B., Fich, L. B., Øien, T. B., & Sørensen, N. L. (2009). *Helende arkitektur.* Aalborg: Institut for Arkitektur og Medieteknologi, Aalborg Universitet.

Gulløv, E., & Højlund, S. (2005). Materialitetens pædagogiske kraft. In K. Larsen (Ed.), *Arkitektur, krop og læring*. Hans Reitzel.

Horsburgh Jr, C. R. (1995). Healing by design. *New England Journal of Medicine, 333*(11), 735-740.

Jonsson, O., Östlund, B., Warell, A., & Dalholm Hornyánszky, E. (2014). Furniture in swedish nursing homes: A design perspective on perceived meanings within the physical environment. *Journal of Interior Design, 39*(2), 17-35.

Kjærsig, K., & Linaa, L. (2015). *Livet mellem stuerne - Inspirationskatalog til gangarealer, vente- og opholdsmiljøer på OUH [Life between bedroom - inspirational catalogue for hospital wards, waiting areas and dayrooms at odense university hospital]*. Odense, Denmark: Syddansk Sundhedsinnovation.

Kvale, S. (1997). *InterView: En introduktion til det kvalitative forskningsinterview.* Kbh.: Hans Reitzel.

Lawson, B., Phiri, M., & Wells-Thorpe, J. (2003). *The architectural healthcare environment and its effects on patient health outcomes*. NHS Estates.

Lemche, J. (2012). *Den gode sundhedsarkitektur : Patienters, arkitekters og bygherrers italesættelser af fremtidens sundhedsbygninger: erhvervsPhD-afhandling*. Odense: Syddansk Universitet.

Lewicka, M. (2011). Place attachment: How far have we come in the last 40 years? *Journal of Environmental Psychology, 31*(3), 207-230.

Malone, E.B. & Dellinger, B.A. 2011, *Furniture design features and healthcare outcomes*, Concord, CA: The Center for Health Design.

Morgan-Brown, M., Newton, R. & Ormerod, M. (2013). Engaging life in two Irish nursing home units for people with dementia: Quantitative comparisons before and after implementing household environments. *Aging & mental health,* vol. 17, no. 1, pp. 57-65.

Mogensen, J. E., Fisker, A. M., & Poulsen, S. B. (2014). Interior textiles and the concept of atmospheres - A case study on the architectural potential of textiles in danish hospital interiors. *14th Biennial Symposium Proceedings: New Directions: Examining the Past, Creating the Future,*

Mogensen, J.E., Jørgensen, P.-E., & Poulsen, S. (2014). Design innovations and implementation challenges - A case of smart textiles in future hospital interiors. *DS 77: Proceedings of the DESIGN 2014 13th International Design Conference,* 935-945.

Mogensen, J.E., Jørgensen, P.-E., & Thomsen, T. R. (2015). A microbiological evaluation of SiO2-coated textiles in hospital interiors: The effect of passive coatings on the cleaning potential of interior textiles. *Journal of Industrial Textiles,* doi:10.1177/1528083715580543

Pallasmaa, J. (2001). The mind of the environment. In B. Cold (Ed.), *Aesthetics, well-being and health - essays within architecture and environmental aesthetics* (pp. 203-221). England: Ashgate Publishing Limited.

Purcell, A. T., & Nasar, J. L. (1995). Experiencing other people's houses: A model of similarities and differences in environmental experience. In L. Groat (Ed.), *Readings in environmental psychology - giving places meaning* (1st ed., pp. 201-219). London: Academic Press.

Salonen, H., Lahtinen, M., Lappalainen, S., Nevala, N., Knibbs, L.D., Morawska, L. & Reijula, K. (2013). Physical characteristics of the indoor environment that affect health and wellbeing in healthcare facilities: a review. *Intelligent Buildings International,* vol. 5, no. 1, pp. 3-25.

Shin, J. (2004). Hospital birthing room design: A study of mothers' perception of hominess. *Journal of Interior Design,* vol. 30, no. 1, pp. 23-36.

Sjørslev, I. (2007). Husets univers - om dansk enfamilehuse i tid og rum. *Dansk Socilogi, 4*, 18.

Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H., Choi, Y., . . . Joseph, A. (2008). A review of the research literature on evidence-based healthcare design. *Health Environments Research & Design Journal, 1*(3), 61-125.

Ulrich, R. S. (1991). Effects of interior design on wellness: Theory and recent scientific research. *Journal of Health Care Interior Design, 3*, 97-109.

Vacher, M. (2006). Hjemmet - kulmination af en tilegnende praksis. *Center for Boligforskning* [Online], Available from: http://boligforskning.dk/node/213 [Accessed: 20.7.2014].

Winther, I. W. (2006). *Hjemlighed : Kulturfænomenologiske studier / ida wentzel winther* Kbh. : Danmarks Pædagogiske Universitets Forlag.

Zavotka, S. L., & Teaford, M. H. (1997). The design of shared social spaces in assisted living residences for older adults. *Journal of Interior Design, 23*(2), 2-16.

Zumthor, P. (2006). In Zumthor P. (Ed.), *Atmospheres: Architectural environments - surrounding objects.* Birkhäuser, Basel.

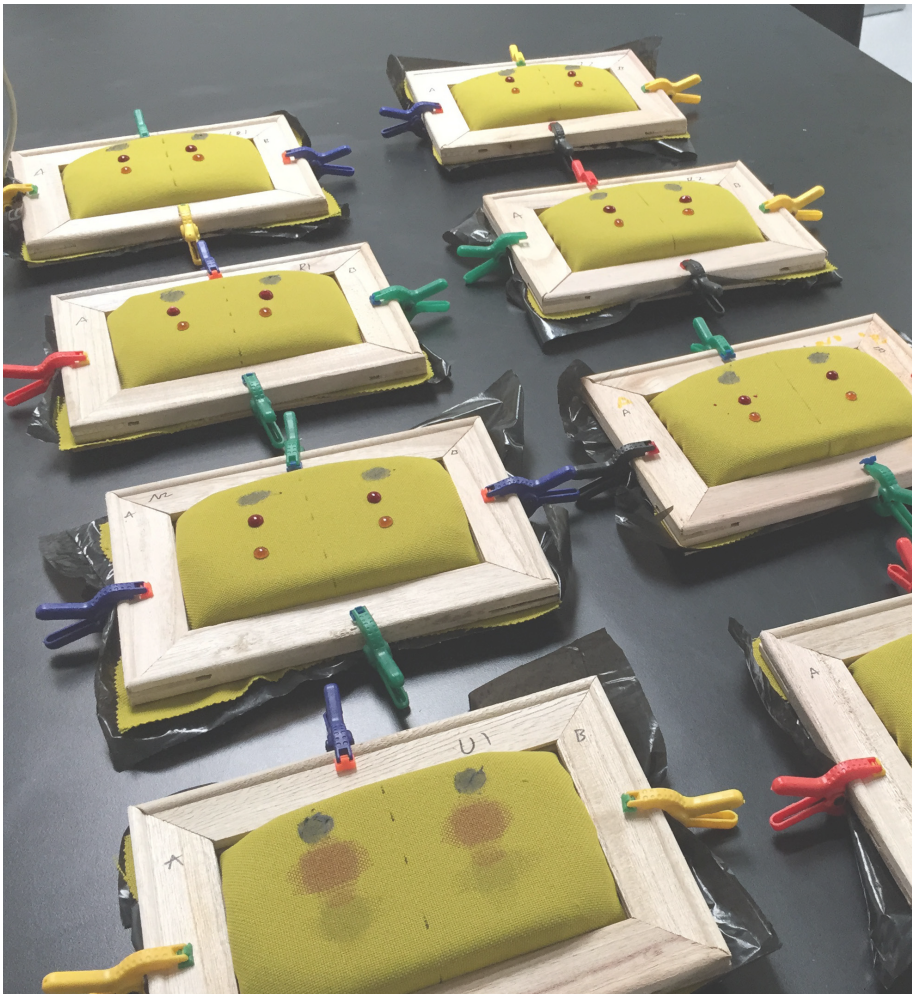
APPENDED REPORT

REPORT C

Mogensen, J & Jørgensen, P-E 2015, *Tekstiler til fremtidens hospitaler – rengøring og desinfektion af funktionelle tekstiler - [Textiles for future hospitals – cleaning and disinfection of functional textiles]*. Report published by VIA Design, VIA University College, Denmark.

Tekstiler til Fremtidens Hospitaler

Rengøring og desinfektion af funktionelle tekstiler



VIA University College

Innovationsnetværket
Livsstil - Bolig & Beklædning
Innonet Lifestyle - Interior & Clothing

TEKNOLOGISK INSTITUT

Tekstiler til fremtidens hospitaler -
Rengøring og desinfektion af funktionelle tekstiler

Rapporten er udarbejdet som afslutning på projektet "Tekstiler til Fremtidens Hospitaler", der er finansieret af Innovationsnetværket Livsstil - Bolig og Beklædning. Projektet er gennemført i 2014-2015 i et samarbejde mellem VIA Smart Textiles, VIA Design, VIA University College og Teknologisk Institut.

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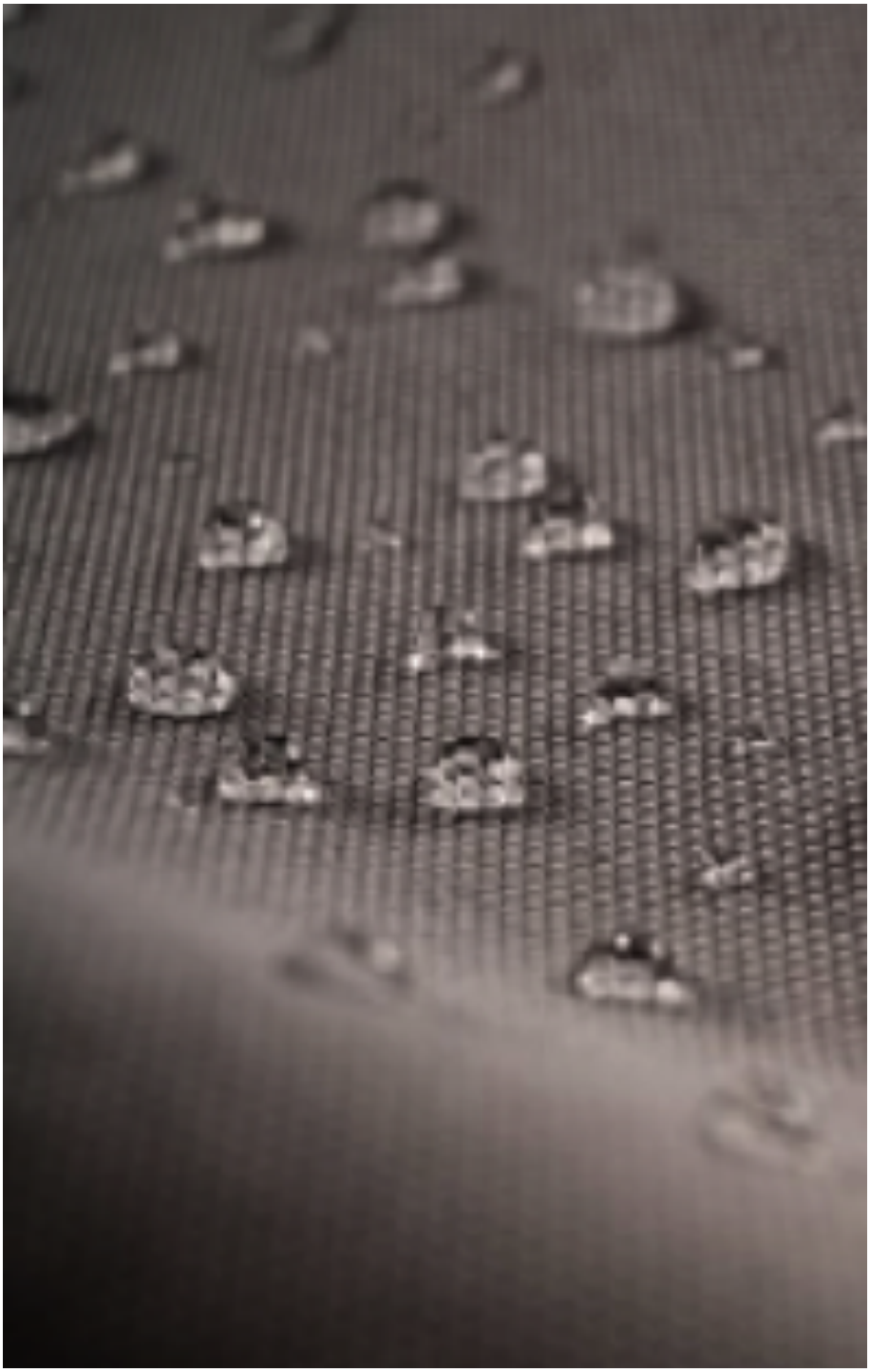
Indhold



Introduktion

I forbindelse med opførslen af nye hospitaler i Danmark, er der kommet fokus på nye designløsninger, der vil kunne fremme driften af disse super-sygehuse.
Med et ønske om at styrke patientoplevelsen, opføres de nye hospitaler overordnet ud fra designbegrebet 'helende arkitektur', der repræsenterer visionen om en hurtige helingsproces for indlagte patienter, understøttet af stimulerende design og arkitektur.
Udviklingen og anvendelsen af nye indretningsmaterialer er dog et overset område i relation til helende arkitektur, selvom materialerne vurderes at have stor betydning for oplevelsen af det fysiske miljø.

Med de høje krav til hygiejne og rengøring, er materialevalget til hospitalets indretning ofte begrænset til hårde, glatte og rengøringsvenlige overflader. Møbler og inventar skal nemt kunne renholdes og desinficeres, og for at effektivisere rengøringsprocessen, er traditionelle tekstiler langsomt blevet udfaset fra hospitalsindretningen. De bløde, komfortable møbeltekstiler erstattes i stedet af polyurethan coatede materialer, der med en tæt overflade nemt kan rengøres, men som dog ikke besidder samme æstetiske og komfortmæssige kvaliteter, der kan supplere visionerne for helende arkitektur.

Der findes dog en række interessante løsninger indenfor feltet 'funktionelle tekstiler', som umiddelbart ville kunne forene de æstetiske og funktionelle aspekter, der er essentielle i moderne hospitalsdrift. Med en overfladecoating, kan tekstilerne behandles så de opnår en hydrofobisk og rengøringsvenlig overflade, så materialerne potentielt kan rengøres på lige fod med de plastik coatede materialer, der anvendes som alternativ. Disse materialer har dog endnu ikke fundet anvendelse på danske hospitaler, da der mangler kontekstuel viden om mulighederne og udfordringerne ved at anvende de nye typer tekstiler i hospitalsmiljøet.
Med et ønske om at bidrage til udviklingen af nye indretningsmaterialer til fremtidens hospitaler, er det projektets overordnede formål at undersøge hvordan forskellige overfladebehandlede tekstiler kan renholdes og desinficeres i relation til de gældende hygiejnekrav og standarder for hospitalsrengøring.

Rapporten her vil således formidle resultaterne fra 3 forskellige delstudier. Et rengøringsforsøg, et desinfektionsforsøg, og et studie af de overfladebehandlede tekstilers slidstyrke. Før fremgangsmåden og resultaterne for disse forsøg præsenteres, vil et kort afsnit præcisere de centrale udfordringer, der er ved anvendelse af tekstiler på hospitalerne.

Hospitaler og tekstiler

Hospitalernes rengøringsniveau har de seneste år været omdiskuteret og forskellige initiativer til at forbedre hygiejnen er blevet igangsat. Tidligere, har danske studier påvist at omkring 10 % af alle patienter på danske hospitaler får en infektion under deres indlæggelse, og initiativer til at forbedre rengøringen på hospitalerne er nødvendige for at opretholde og forbedre patientsikkerheden. Fokus på rengøringsvenlige materialer er derfor essentiel, og overgangen til de polyurethan coatede tekstiler, der anvendes på mange hospitaler idag, er umiddelbar forståelig. Traditionelle tekstiler er i internationale forskningsstudier blevet fremhævet som potentielle bakterie reservoirs, og de udgør således en mulig kilde til smitte mellem patienter. Studierne påviser dog også, at selv de glatte plastik overflader giver mulighed for at bakterier kan overleve på overfladen i flere uger (Noskin et al. 2000, Lankford et al. 2006, Huang et al. 2006).
De glatte overflader kan dog nemmere rengøres, ligesom de kan desinficeres ved overtørring med klor eller sprit. Her skal de traditionelle tekstiler i stedet afmonteres og vaskes, hvilket ofte vil være mere omkostningstungt.

Funktionelle tekstiler

Indenfor de senere år er der blevet udviklet flere tekstiler med antibakterielle egenskaber. Disse tekstiler er enten overfladebehandlet, så tekstilet får en bakteriedræbende effekt, eller der kan være indlejret antibakterielle elementer i selve tekstilfibrene. Især produkter med nanosølv er blevet markedsført intenst indenfor både forbrugerprodukter og tekstile løsninger til bl.a. hospitaler.

I Danmark er der ingen formelle forbud mod anvendelsen af de antibakterielle tekstiler, men holdningen hos Statens Serum Institut (SSI), der rådgiver indenfor hospitalsrengøring og -hygiejne, er at antibakterielle tekstiler ikke bør anvendes på danske hospitaler.

"Indhold af særlige antimikrobielle stoffer til inventar, udstyr og tekstiler anbefales på nuværende tidspunkt ikke, da der generelt mangler viden om varighed af effekt, risiko for afgivelse af stof til det omgivende miljø samt risiko for udvikling af resistens hos mikroorganismer i miljøet og i patienters og personales normalflora."
(Statens Serum Institut 2013)

Selvom de antibakterielle tekstiler kan have en gavnlig effekt og nedbringe bakterieniveauet, er risiciene på et niveau, der ikke gør materialerne egnet herhjemme.
I stedet, sætter projektet her derfor fokus på hydrofobiske, rengøringsvenlige tekstiler, der uden aktivt at dræbe bakterierne, giver en passiv vand- og smudsafvisende overflade. Det er projektets hypotese, at disse overflader vil kunne rengøres ud fra hospitalernes nuværende rengøringsmetoder, og at de kan desinficeres ved nye innovative desinfektionsmetoder.

Rengøring på hospitalerne

For at de rengøringsvenlige funktionelle tekstiler skal være interessante som alternativ til de polyurethan coatede tekstiler, skal rengøring og desinfektion af tekstilerne kunne optimeres i forhold til traditionelle tekstiler.

For at kunne undersøge dette, vil dette afsnit kort definere de rengørings- og desinfektionskrav, der er til indretningsmaterialer på hospitalerne.
I relation til hospitalshygiejne skelnes der mellem rengøring og desinfektion. Rengøring har til formål at fjerne støv, smuds og mikroorganismer for at forhindre en opformering af mikroorganismer, mens der ved desinfektion forstås en proces, der er i stand til at dræbe patogene mikroorganismer i et sådant omfang, at det desinficerede kan benyttes uden risiko for infektion.

Rengøring på hospitalerne følger i dag en række guidelines og vejledninger under Dansk Standard. Indretningstekstiler skal derved behandles i henhold til DS2451 del 8. ”Krav til vask og håndtering af tekstiler til flergangsbrug”, der foreskriver vask ved 80 grader i 10 min, eller anvendelse af kemisk desinfektionsmiddel med samme effekt.

Den øvrige rengøring af hospitalets inventar og udstyr er beskrevet i DS2451 del 10 ”Krav til rengøring”.

Rengøringen af hospitalet skal ifølge DS2451 del 10, udføres tilstrækkeligt hyppigt så lokaler og inventar fremstår visuelt rent. Formålet med rengøringen er således at fjerne potentielt smitstof fra inventar og lokalers overflader, og rengøringen vurderes ud fra en visuel bedømmelse af 10 risikopunkter i de enkelte lokaler.
Møbler betragtes i den forbindelse som et patientleje, der jf. standarden skal rengøres efter rengøringsmetode 3, hvilket vil sige overtørring med en ren fugtig klud tilsat rengøringsmiddel med mekanisk bearbejdning af overfladen. Ved høj besmudsning kan rengøringsmetode 4 anvendes, hvor rengøringen er våd men ellers efter samme princip som metode 3.

I tilfælde af spild af humanbiologisk materiale, skal der foretages en rengøring efter metode 3 eller 4, efterfulgt af en desinfektion. Alt synligt humanbiologisk materiale skal være fjernet efter endt rengøring.

Desinfektion af hospital inventarets overflader anvendes, når en reduktion i antallet af patogene mikroorganismer kan mindske risikoen for infektion, men en total kimfrihed ikke er nødvendig (som ved sterilisation).

Statens Serum Institut (SSI) har udgivet de Nationale Infektionshygiejniske Retningslinjer for desinfektion af overflader på hospitaler (Statens Serum Institut 2014). Her fremgår det, at i langt de fleste rum på sygehuse kan ikke-kritisk udstyr (kontakt via intakt hud) og inventar holdes rent med almindeligt anvendte rengøringsmetoder. Kun ved udbrudssituationer eller ved spild af humanbiologisk materiale, kan det være nødvendigt at supplere rengøringen med en overfladedesinfektion.

Man tilsigter at bruge varme som desinfektion i alle de tilfælde, hvor det er muligt. Alternativt kan kemisk desinfektion anvendes.
Desinfektionsprocessen opdeles i 3 niveauer (1: 'Maksimal antibakteriel effekt', 2: 'Medium antibakteriel effekt', 3: 'Lav antibakteriel effekt').

I tilfælde af spild af humanbiologisk materiale, eller ved de fleste tilfælde af smitstof, anvendes et desinfektionsmiddel med 'medium antibakteriel effekt' (eks. alkohol). Ved forekomst af visse bakterier skal der i stedet anvendes et middel med 'maksimal antibakteriel effekt' (eks. klor).
Processen for desinfektion foreskriver, at synligt forurenede overflader rengøres. Herefter påføres desinfektionsmiddel fx på en ren klud så kluden er gennemvædet. Rene overflader bearbejdes så alle områder kommer i kontakt med desinfektionsmidlet. Overfladen efterlades våd og må ikke benyttes før den er tør.

Overfladedesinfektion af inventar forudsætter i alle tilfælde en grundig forudgående rengøring, da desinfektionsmidlers effekt forudsætter direkte kontakt mellem mikroorganismerne og aktivstoffet i desinfektionsmidlerne.

Som det fremgår af Dansk Standards krav til rengøring på hospitaler, skal alle møbeloverflader, herunder tekstiler, således kunne renholdes i daglig praksis ved overtørring med en fugtig klud tilsat rengøringsmiddel. Derudover skal der ved tilfælde af spild af humanbiologisk materiale eller ved særlige udbrud være muligt at desinficere overfladen med enten varmedesinfektion, kemisk desinfektion (alkohol eller klor) eller tilsvarende desinfektionsmetode.

Formål og metode

Kravene til indretningsmaterialer på hospitalerne er omfattende, men indenfor feltet af funktionelle tekstiler, er der en række interessante løsninger, som potentielt vil kunne anvendes på hospitalerne. Formålet med de følgende studier er således at undersøge om disse hydrofobiske tekstiler vil kunne rengøres og desinficeres til et acceptabelt niveau, der gør materialerne egnet til anvendelse i en fremtidig hospitalskontekst. Studiet opdeles i 3 dele, der har til hensigt at undersøge de to overordnede betingelser for henholdsvis rengøring og desinfektion, og endeligt at undersøge de hydrofobiske tekstilers slidstyrke.

Materialer

Tekstiler

Til alle forsøg anvendes det samme tekstil som grundmateriale. Her er udvalgt et Trevira CS baseret møbeltekstil (Gabriel Step), der opfylder de grundlæggende krav til anvendelse på hospitalerne.

Overfladebehandlinger

For at teste de hydrofobiske coatingers rengørings- og desinfektionsevne, er der udvalgt 3 forskellige overfladebehandlinger, baseret på forskelige teknologier.

Tabel 1: Tekstiler og overfladebehandlinger

Beskrivelse	Produkt	Producent	Teknologi
Ubehandlet	Gabriel, Step	Gabriel	Ubehandlet
Overfladebehandling 1	NP	NanoPool	Siliciumdioxid
Overfladebehandling 2	zeroF	CHT/BEZEMA	Paraffin
Overfladebehandling 3	Repellan	PulcraChemicals	Paraffin

Fremgangsmåde

Som beskrevet er forsøget opdelt i 3 delelementer, hvor rengøring (synlig snavs), desinfektion (bakteriedræbende effekt) og slidstyrke (overfladernes holdbarhed) vil blive undersøgt særskilt gennem 3 studier.

Metoderne for hver af de 3 studier beskrives i de følgende afsnit.

Metode - rengøringsforsøg

Formålet med rengøringsforsøget er specifikt at undersøge hvordan tekstiloverfladerne kan rengøres ud fra den gældende rengøringsmetode, der anvendes på hospitalerne i dag jf. DS2451 del 10.

De forskellige tekstiler (ubehandlet reference og de 3 behandlede tekstiler) monteres i hver deres træramme, så de ligger udspændt mod en underflade af plastikbeklædt skumpolster. Herefter besmudses tekstilerne med repræsentative smudstyper, herunder en vandholdig, fedtholdig og proteinholdig smuds. Se tabel nedenfor.

Tabel 2: Smudstyper anvendt til rengøringsforsøget

Smudstype	Beskrivelse	Reference
Vandholdig	Kaffe	DFD
Fedtholdig	Svinefedt/sod (farveindikator)	Fijan et al. 2007
Proteinholdig	Svineblod	DFD, Fijan et al. 2007

Der påføres ca. 1 ml af hver type smuds på hver af tekstiloverfladerne, der herefter stilles til tørring i 24 timer ved 20 grader.

Efter tørring rengøres tekstilerne ud fra DS2451 del 10, rengøringsmetode 3, der er en aftørring med fugtig klud. Tekstilet rengøres i op til 60 sekunder, indtil pletten er fjernet.
Herefter placeres tekstilet i tørreskab ved 60 grader i 1 time, før der foretages visuel vurdering af renhedsgraden.

Tekstilets visuelle renlighed vurderes efter en 5 trins gråskala (ISO 105-A03) i henholdsvis dagslys og kunstlys (TL84), hvor 1 repræsenterer et ikke-rent tekstil, mens 5 repræsenterer et helt-rent tekstil, hvor der ikke kan ses synlig variation i forhold til et ikke-besmudset tekstil.
I det tilfælde at tekstilet stadig ikke er rent, gentages forsøget på de pletter, der stadig er synlige med rengøringsmetode 4 jf. DS2451 del 10, som foreskriver en våd rengøring, efterfulgt af aftørring med tør klud.
Herefter tørres tekstilerne igen i varmeskab (60 grader i 1 time), og renligheden vurderes igen visuelt ud fra gråskalaen.

Forsøget gennemføres med 4 gentagelser, hvor det dårligste resultat medtages til resultatoversigten.

Metode - desinfektionsforsøg

En af de væsentlige problemstillinger ved brugen af tekstiler på hospitalerne er krav om desinfektion i tilfælde bakterie udbrud på afdelingen eller ved spild af humanbiologisk materiale. Traditionel vask, som vil kunne udgøre en metode til desinfektion, vurderes ofte til at være for ressourcekrævende, og den polyurethan coatede overflade, som kan aftørres med sprit eller klor for fuld desinfektion, anvendes derfor i stedet.
For at undersøge de overfladebehandlede tekstilers mulighed for desinfektion, afprøves først en traditionel desinfektionsmetode, hvor tekstiloverfladerne desinficeres med klor, og dernæst afprøves SonoSteam (kombination af damp og ultralyd) som en alternativ desinfektionsmetode.

Desinfektionsmetode 1 - Overtørring med klor

Ifølge de Nationale Infektionshygiejniske Retningslinier (Statens Serum Institut 2014), kan overflader desinficeres til 'maksimal antibakteriel effekt', ved overtørring med klor. Formålet med dette første desinfektionsforsøg er derfor at undersøge effekten af denne traditionelle desinfektionsmetode.

De forskellige tekstiler udspændes i trærammer over et stykke plastikbeklædt skumgummi, hvorefter der påføres 1 ml TVC bakteriekoncentrat på tekstilerne. Bakterievæsken spredes ud over et afmærket område og stilles til tørring i 24 timer. Efter tørring måles bakterieniveauet med Total Count Dipslides for at bekræfte at tekstilerne har været podet med bakterier før desinfektionen. Tekstiloverfladerne desinficeres dernæst med klor (WetWipe Chlorine, >1000 ppm aktiv klor). Ved denne desinfektionsproces gennemvædes tekstilerne og de stilles igen til tørring i 24 timer. Tekstilerne sendes herefter til Teknologisk Institut for en endelig vurdering af bakterieniveauet efter desinfektion.

Desinfektionsmetode 2 - SonoSteam

SonoSteam er en desinfektionsproces, der udnytter en kombination af damp og ultralyd til at opnå en varmebaseret desinfektion på få sekunder. Systemet er oprindeligt udviklet til fødevareindustrien, men gode resultater er også opnået indenfor overfladedesinfektion, hvor systemet bl.a. testes for desinfektion af hospitalsmadrasser på Hvidovre hospital.

Ved traditionel damp rengøring, fungerer luftlaget tæt på overfladen som et beskyttende lag, der hindrer effektiv varmeudveksling med overfladen. Ultralyden påvirker ved SonoSteam behandlingen dette luftlag og sætter det i bevægelse, hvilket gør det muligt for den varme damp at komme i kontakt med overfladen og dens mikro-strukturer. På grund af mikroorganismernes størrelse, vil de hurtigt blive påvirket af varmen fra dampen og bliver dræbt inden varmen påvirker selve objektet, der bliver behandlet.

Fremgangsmåde

De 3 forskellige hydrofobiske tekstiler og den ubehandlede version klippes ud så de passer i FORCE Technology's SonoSteam testudstyr.
Der laves 4 versioner af hver overflade, hvor 2 af overfladerne desinficeres, mens de 2 andre overflader udgør en kontrol, der ikke får SonoSteam behandlingen.

Tekstilerne podes med en 1 ml opløsning af TVC bakterier (log-5 koncentration). På de overfladebehandlede tekstiler smøres bakterievæsken ud, så den dækker et tyndt jævnt lag, og tekstilerne stilles herefter til tørring, indtil overfladen fremstår tør og uden vandspejl.

Desinfektionsbehandlingen sættes som udgangspunkt til 1 sekund, da dette korte tidsinterval ikke påvirker tekstilets udseende. Med dette studie, er det således muligt at se hvilken effekt 1 sekund behandling har på de forskellige tekstiloverflader. Selve behandlingen i SonoSteam udstyret kan efterfølgende finjusteres i forhold til tekstiltype, overflade, etc.

Efter SonoSteam behandlingen undersøges bakterieniveauet på tekstiloverfladerne (både kontrolgruppen og de SonoSteam behandlede tekstiler). Her placeres tekstilet i en stomacher pose sammen med 90 mL buffer pepton vand, og det pulsifiseres i 30 sekunder og indholdet hældes tilbage i flasken.
Flasken med ekstraktionsvæske for hver af de enkelte tekstilprøver omrystes, og udplades på petrifilm i 5 10-ganges fortyndinger (trypton-salt fortyndingsrør).
Petrifilm prøverne inkuberes i 72 timer og tælles.

Ill. 1: SonoSteam - udstyr til desinfektion

Ill. 2: SonoSteam - damp/ultralyd dyser

Metode - slidstyrke

En af udfordringerne ved anvendelse af nye overfladebehandlinger på tekstiler i hospitalssektoren er holdbarhed og slidstyrke på coatingen. For at rengøringsmuligheden skal opretholdes over længere tid, skal den vand- og smudsafvisende overflade have en bestandighed, der gør den egnet til hospitalsbrug. For at undersøge slidstyrken på de forskellige overflader, gennemføres en slidtest ved Martindale-metoden (DS/EN ISO 12947), og overfladens bestandighed undersøges med en dråbetest (DS/ISO 23232 – Prøvning med vand-alkohol-opløsning).

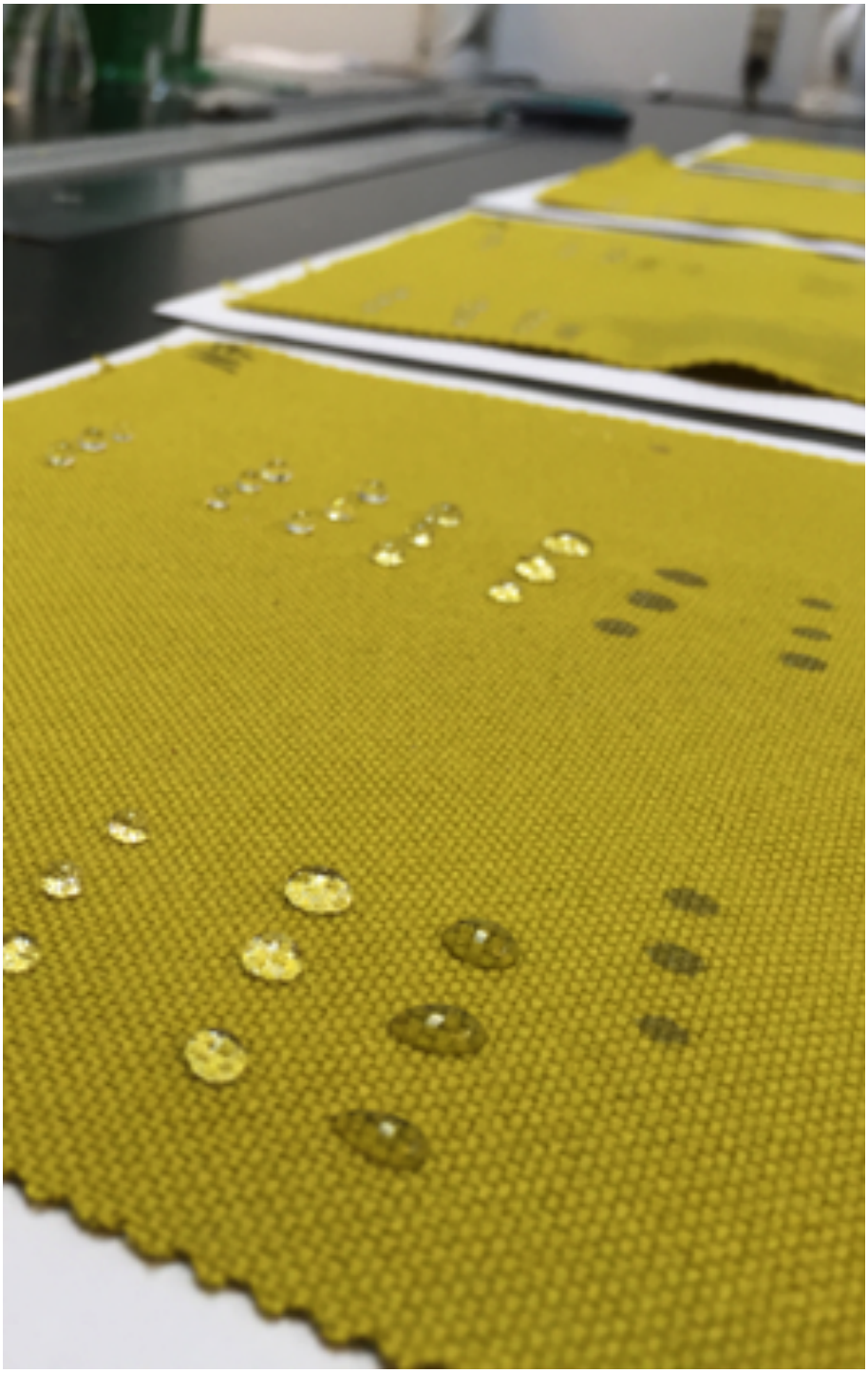
Ved at variere vand-alkohol forholdet i opløsningen, ændres overfladespændingen, og ved at placere dråber af opløsningen på tekstiloverfladerne, kan den vandafvisende evne bestemmes. Skema over opløsninger og deres overfladespænding er beskrevet nedenfor.

Tabel 3: Opløsninger og overfladespænding

Grad af vandafvisning	Opløsning	Overfladespænding ved 25 grader (dyn/cm)
0	Ingen – fejler test 1	-
1	98:2 (vand/isopropyl alkohol)	59.0
2	95:2 (vand/isopropyl alkohol)	50,0
3	90:10 (vand/isopropyl alkohol)	42,0
4	80:20 (vand/isopropyl alkohol)	33,0
5	70:30 (vand/isopropyl alkohol)	27,5
6	60:40 (vand/isopropyl alkohol)	25,4
7	50:50 (vand/isopropyl alkohol)	24,5
8	40:60 (vand/isopropyl alkohol)	24,0

Dråberne placeres på tekstiloverfladerne med en pipette, og de observeres i 10 sekunder, hvorefter det vurderes om dråben holdes oppe eller om den siver ned i tekstilet.

Tekstiloverfladernes hydrofobiske effekt bestemmes herefter for forskellige grader af slid, der påføres ved Martindale-metoden. Tekstilerne testes ved henholdsvis 2.500, 5.000, 7.500, 10.000, 15.000, 20.000, 30.000, 40.000, 50.000, 60.000 Martindale.



Resultater

Rengøringsforsøg

Resultat for rengøringsforsøg er nedenfor præsenteret i en samlet tabel.

Tabel 4: Resultater efter rengøring ved rengøringsmetode 3

Smudstype	Ubehandlet		NanoPool		zeroF		Repellan	
	Dagslys	Kunstlys	Dagslys	Kunstlys	Dagslys	Kunstlys	Dagslys	Kunstlys
Svinefedt/ sod	1	1	1	1	1	1	1	1
Svineblod	1	1	4	4	5	5	4	3/4
Kaffe	3	3	4	4	5	5	4/5	4/5

Som det fremgår af tabellen, er svinefedt/sod smudset ikke mulig at fjerne fra nogle af de 4 tekstiloverflader. Det virker til at hæfte for godt til tekstilets overflade, og rengøringsmetoden formår ikke at opløse fedtpartiklerne.
Derimod er både svineblod og kaffe mulige at rengøre fra de hydrofobiske tekstiler. På det ubehandlede tekstil, er disse smudstyper dog trukket ind i fibrene, og de er ikke mulige at fjerne her. På de overfladebehandlede tekstiler derimod, har smudset – trods indtørring efter 24 timer – lagt sig ovenpå tekstilfibrenes, og de kan her fjernes med rengøringsmetode 3. Efter tekstilerne har ligget i tørreskab i 1 time, er enkelte af pletterne dog stadig svagt synlige, som det fremgår af resultaterne ovenfor.

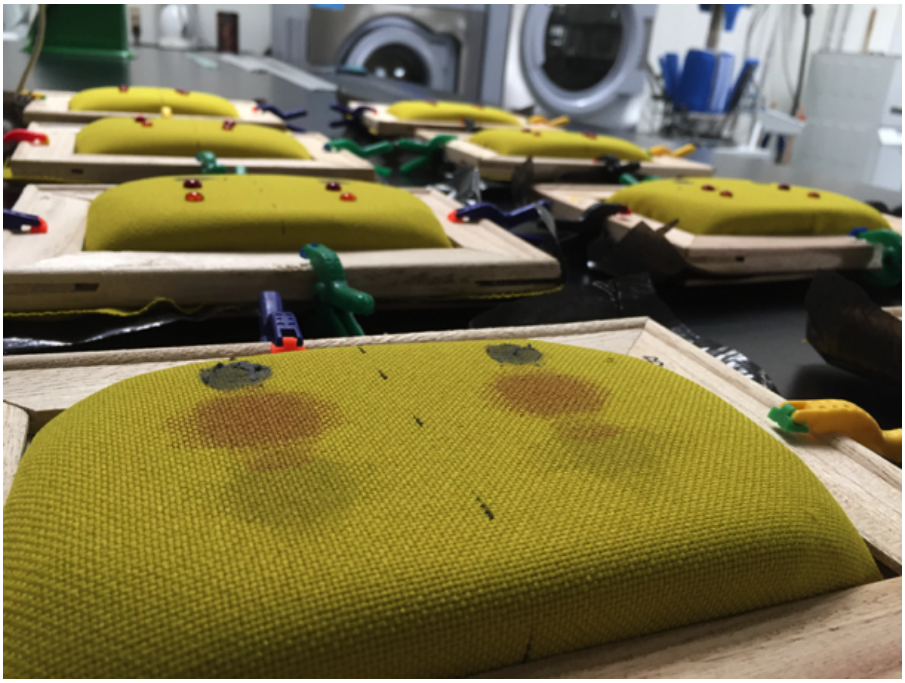
Tekstilerne, der ikke har opnået en fuldstændig renlighed ved rengøringsmetode 3, forsøges herefter rengjort med rengøringsmetode 4 for at se om tekstilet kan blive helt ren ved en våd rengøringsmetode. I forhold til tekstilernes vandafvisende overflade, vil anvendelsen af en mere våd rengøring forventelig kunne opløse mere af den indtørrede smuds, uden at det trænger ned i de overfladebehandlede tekstilfibre.

Tabel 5: Resultater efter rengøring ved rengøringsmetode 4

Smudstype	Ubehandlet		NanoPool		zeroF		Repellan	
	Dagslys	Kunstlys	Dagslys	Kunstlys	Dagslys	Kunstlys	Dagslys	Kunstlys
Svinefedt/ sod	1	1	1	1	1	1	1	1
Svineblod	1	1	5	5	5	5	4/5	4/5
Kaffe	3	3	5	5	5	5	4/5	4/5

Efter rengøring med våd rengøringsmetode jf. Dansk Standard 2451-10, er NanoPool overfladerne blevet fuldstændig rene ved en visuel vurdering, mens der også ses et forbedret rengøringsniveau på Repellan overfladerne. Der er dog stadig meget svagt synlige nuanceforskelle, der hvor pletterne har været, og de opnår derfor ikke den fulde karakter 5.

Resultaterne af rengøringsforsøget viser generelt, at de overfladebehandlede tekstiler kan rengøres med de nuværende metoder til et visuelt acceptabelt niveau for de vandholdige og proteinholdige smudstyper, mens overfladerne med den fedtholdige smuds ikke er mulig at rengøre i nogle af forsøgene.



Ill. 3: Tekstiloverflader besmudset med fedt, blod og kaffe.

Desinfektionsforsøg

Resultatet for desinfektion med henholdsvis klor og SonoSteam damp/ultralydsbehandlingen er sammenfattet i tabellerne nedenfor.

Desinfektionsmetode 1 - Behandling med klor

Tabellen viser bakterieniveauet før desinfektion, vurderet ud fra dipslides, og Teknologisk Instituts målinger af bakterieniveauet på for- og bagside af tekstilerne efter desinfektion.

Tabel 6: Desinfektion af tekstiler ved overtørring med klor

			Bakterieniveau Før desinfektion	**Bakterieniveau** Efter desinfektion
Ubehandlet	*Prøve 1*	*Forside*	>15 CFU/cm2	5,9
		Bagside		≈22,2
	Prøve 2	*Forside*	>15 CFU/cm2	≈16,7
		Bagside		>22,2
NanoPool	*Prøve 1*	*Forside*	>15 CFU/cm2	0,9
		Bagside		0,8
	Prøve 2	*Forside*	>15 CFU/cm2	7,6
		Bagside		8,6
zeroF	*Prøve 1*	*Forside*	>15 CFU/cm2	2,3
		Bagside		1,9
	Prøve 2	*Forside*	>15 CFU/cm2	0,9
		Bagside		2,3
Repellan	*Prøve 1*	*Forside*	>15 CFU/cm2	0,2
		Bagside		0,2
	Prøve 2	*Forside*	>15 CFU/cm2	0,4
		Bagside		1,3

Note: Bakterieniveauet er ikke målt på bagsiden før desinfektion.

Som resultaterne viser er behandlingen med klor effektiv til at desinficere enkelte af de overflade-behandlede tekstiloverflader. De fleste af prøverne viser således et bakterieniveau, der er under 2,5 CFU/cm2, hvilket i henhold til DS 2451-10 angiver et tilstrækkeligt rent overflade niveau efter rengøring. Enkelte af prøverne viser dog et bakterieniveau, der er væsentlig over de 2,5 CFU/cm2, og studiet giver derfor ikke entydige indikationer på effektiviteten. Der bør derfor gennemføres yderligere studier af dette for at undersøge klors effektivitet på de hydrofobiske overflader. Især med fokus på bakteriernes spredning i tekstilerne, hvor forsøget her viser at bakterierne også er repræsentative på tekstilets bagside, hvor simpel desinfektion med overtørring kan være vans-

keliggjort når tekstilet er fastmonteret på hospitalsmøbler og lignende.
Forsøget viser desuden en klar reduktion af bakterier på de behandlede tekstiler sammenlignet med det ubehandlede tekstil, hvilket kan skyldes at bakteriernes vækstbetingelser på de hydrofobe tekstiloverflader er forringet. Denne passive bakteriereducerende effekt er af tidligere studier koblet til de hydrofobe tekstilers lavere overfladeenergi (Yao, Song & Jiang 2011; Zhao, Wang & Müller-Steinhagen 2004; Tomšic et al. 2008), men bør undersøges nærmere for de specifikke tekstiler i efterfølgende studier.

Desinfektionsmetode 2 - SonoSteam

Resultatet for SonoSteam desinfektion er opgjort for henholdsvis CFU/ml (svarende til 1 ml pulsificeret pepton vand) og en CFU log-værdi svarende til hele stofstykket med 1 ml TVC bakterieopløsning.

Tabel 7: Desinfektion af tekstiler ved 1 sekund SonoSteam behandling

		CFU (gennemsnit pr. ml)	CFU - log (gennemsnit pr. 90 ml)	Reduktion (%)	Reduktion (log)
Ubehandlet	*Control*	2.627	5,37	99,99 %	4,39
	SonoSteam	0,5	0,98		
NanoPool	*Control*	364	4,51	99,66 %	3,53
	SonoSteam	0,5	0,98		
zeroF	*Control*	418	4,57	99,99%	2,47
	SonoSteam	1,5	2,10		
Repellan	*Control*	2.827	5,15	99,97 %	4,02
	SonoSteam	1	1,13		

Som det fremgår, er SonoSteam behandlingen ved 1 sekund effektiv nok til at reducere af bakterierne tæt på 100 %. Efter udpladning, er der maksimalt 2 CFU synlige på de behandlede overflader, som i så lav koncentration også kan skyldes en fejl-kontaminering ved håndtering af petrifilmen i forbindelse med udpladning.

I forsøget er både det ubehandlede tekstil og de funktionelle tekstiler lige modtagelige overfor SonoSteam behandlingen, og der vurderes ikke at være nogen forskel på tekstilernes overflade i den forbindelse. På baggrund af disse resultater, er der umiddelbart gode muligheder for at igangsætte videre studier, der undersøger muligheden for at implementere SonoSteam behandlingen til desinfektion af tekstil-baseret inventar og udstyr på fremtidens hospitaler.

Slidstyrke

For at undersøge overfladebehandlingens holdbarhed undersøges de vandafvisende egenskaber med en vand-alkohol-opløsning efter en slidstyrkeprøve ud fra Martindale-metoden (DS/EN ISO 12947).

Tabel 8: Grad af hydrofobisk effekt i forhold til slid

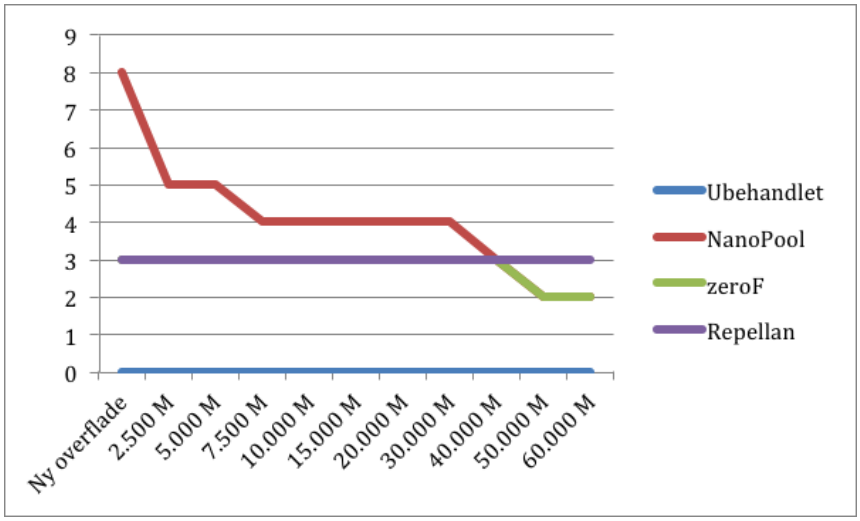
	0 M	2.500 M	5.000 M	7.500 M	10.000 M	15.000 M	20.000 M	30.000 M	40.000 M	50.000 M	60.000 M
Ube-handlet	0	-	-	-	-	-	-	-	-	-	-
Nano-Pool	8	5	5	4	4	4	4	4	3	2	2
zeroF	3	3	3	3	3	3	3	3	3	2	2
Repellan	3	3	3	3	3	3	3	3	3	3	3

Som det fremgår af tabelen, er holdbarheden for de forskellige tekstiloverflader på et gennemgående højt niveau. NanoPool har på en ny overflade (0 Martindale) en hydrofobisk effekt, der svarer til den højeste kategori i vand-alkohol-opløsnings testen. Den vandafvisende evne falder dog allerede ved 2.500 Martindale, og fortsætter faldet ved 7.500 Martindale, hvor den stabiliserer sig helt frem til 30.000 Martindale. Det er uvist hvorfor NanoPool overfladen gradvist mister sin vandafvisende egenskab. ZeroF og Repellan har ikke samme høje udgangsniveau for den hydrofibiske effekt, men begge placerer sig på kategori 3, og hvor Zero falder til kategori 2 ved 40.000 Martindale, holder Repellan den vandafvisende egenskab helt frem til de 60.000 Martindale hvor testen her stoppes.

Holdbarheden er generelt meget positiv i denne test, hvor der alene er fokuseret på slid. Allerede ved 20.000 Martindale, viser stofprøverne tydelige visuelle tegn på slitage, mens den vandafvisende egenskab stadig er fastholdt.

I testen af overfladebehandlingernes holdbarhed, er der alene fokuseret på brugsslid, mens holdbarhed ved traditionel vask ikke er undersøgt, da denne proces generelt ikke er ønsket på hospitalet. Alternative metoder til rengøring og desinfektion skal således udvikles og undersøges, også mht. overfladernes holdbarhed.

Ill. 4: Graf over hydrofobisk effekt i forhold til slid



Konklusion og perspektivering

Formålet med projektet "Tekstiler til Fremtidens Hospitaler", har været at undersøge hvordan funktionelle tekstiler kan renholdes og desinficeres, og dermed at give et overblik over mulighederne for at anvende vandafvisende og rengøringsvenlige tekstiler i indretningen af fremtidens hospitaler.

Gennem de 3 delforsøg, har projektet vist at tekstilerne kunne rengøres for de væskebaserede smudstyper, og at tekstilerne med alternative desinfektionsmetoder kunne opnå en fuld desinfektion.
Den daglige rengøring vurderes at kunne opretholdes med de rengøringsmetoder, der anvendes på hospitalerne i dag, om end der kan være behov for at supplere med andre metoder for at fjerne svære fedtholdige smudstyper.
Desinfektionen med klor, som anvendes på hospitalerne i dag til desinfektion af hårde overflader og møbler betrukket med polyurethan, viser på enkelte af tekstiloverfladerne en god bakteriedræbende effekt, mens andre overflader har et bakterieniveau, der er væsentlig over de 2,5 CFU/cm2. Studiet af denne disinfektionsmetode har derfor ikke givet tydelige indikationer på effektiviteten. Resultatet viser dog en væsentlig reduktion på de overfladebehandlede tekstiler i forhold til traditionelle tekstiler, og muligheden for desinfektion med overfladetørring bør derfor undersøges nærmere i fremtidige studier. SonoSteam behandlingen var, i modsætning til overtørring med klor, mere effektiv og havde en bakteriereduktion meget tæt på 100 % for alle overfladerne. SonoSteam vurderes derfor til at være en potentiel egnet metode til fremtidig desinfektion af indretningstekstiler på hospitalerne, men det vil kræve ændringer i rengøringspraksissen, hvis møbler og inventar skal kunne desinficeres på denne måde fremover. SonoSteam udstyr til desinfektion af møbler og inventar vil skulle placeres centralt på hospitalet, og møbler og inventar skal således transporteres til desinfektionen. For at kunne undersøge hvordan denne logistiske proces bedst kan etableres, vil der være behov for at gennemføre længerevarende, praksisrettede studier, der samtidig vil kunne give et indblik i behovet for den fulde desinfektion.

Med dette projekt er mulighederne for at anvende funktionelle tekstiler i hospitalsindretningen blevet undersøgt, og med baggrund i disse resultater vurderes der at være et umiddelbart fremadrettet potentiale for implementering i hospitalssektoren. Tekstilerne kan renholdes og desinficeres, om end der er behov for andre desinfektionsmetoder, end dem man typisk anvender i dag. Samtidig er slidstyrken på overfladerne på et højt niveau, der giver mulighed for en langvarig effekt selv ved omfattende brug. Længerevarende studier af både rengøringsniveau, desinfektionsproces og slidstyrke vurderes dog at være nødvendige for endeligt at kunne foreslå de funktionelle tekstiler til fremtidens hospitaler.

Referencer

Dansk Standard 2014, DS 2451-10: Infection control in the health care sector - Part 10: Requirements for cleaning, Danish Standard.

Dansk Standard 2013, DS2451-8: Infection control in the health care sector – Requirements for laundering and handling of textiles for multiple use, Dansk Standard.

Fijan, S., Koren, S., Cencič, A. & Šostar-Turk, S. 2007, "Antimicrobial disinfection effect of a laundering procedure for hospital textiles against various indicator bacteria and fungi using different substrates for simulating human excrements", Diagnostic microbiology and infectious disease, vol. 57, no. 3, pp. 251-257.

Huang, R., Mehta, S., Weed, D. & Connie Savor Price, M. 2006, "Methicillin-Resistant Staphylococcus aureus Survival on Hospital Fomites", Infection control and hospital epidemiology, vol. 27, no. 11, pp. 1267-1269.

Lankford, M.G., Collins, S., Youngberg, L., Rooney, D.M., Warren, J.R. & Noskin, G.A. 2006, "Assessment of materials commonly utilized in health care: implications for bacterial survival and transmission", American Journal of Infection Control, vol. 34, no. 5, pp. 258-263.

Noskin, G.A., Bednarz, P., Suriano, T., Reiner, S. & Peterson, L.R. 2000, "Persistent contamination of fabric-covered furniture by vancomycin-resistant enterococci: implications for upholstery selection in hospitals", American Journal of Infection Control, vol. 28, no. 4, pp. 311-313.

Statens Serum Institut 2014, Nationale infektionshygiejniske retningslinjer: For desinfektion i sundhedssektoren, Central Enhed for Infektionshygiejne, SSI.

Statens Serum Institut 2013, Nationale Infektionshygiejniske Retningslinjer: For nybygning og renovering i sundhedssektoren, Central Enhed for Infektionshygiejne.

Tomšic, B., Simoncic, B., Orel, B., Cerne, L., Tavcer, P.F., Zorko, M., Jerman, I., Vilcnik, A., Kovac, J. 2008. "Sol–gel coating of cellulose fibres with antimicrobial and repellent properties"., *J Sol-Gel Sci Technol,* 47: 44-57

Yao, X., Song, Y., Jiang, L., 2011. "Applications of Bio-Inspired Special Wettable Surfaces", *Advanced Materials,* 23: 719-734

Zhao, Q., Wang, S., Müller-Steinhagen, H., 2004. "Tailored surface free energy of membrane diffusers to minimize microbial adhesion", *Applied Surface Science,* 230: 371-378

SUMMARY

This PhD thesis explores the possibilities and design qualities of using functional textiles in the interior of hospital environments, and is the result of a three years collaboration between Aalborg University, Department of Civil Engineering, and VIA University College, VIA Design.

The project is overall related to the construction of new Danish hospitals, where the design concept healing architecture is introduced in a national context, representing the vision of a promoted healing process of hospitalised patients, supported by design related influence. Past research studies provides evidence that the physical environments affect the patients' level of stress and influence their process of recovery and healing. However, although research in this field of hospital design has increased substantially in recent years, knowledge on the use of new materials and textiles in hospital interiors is still rather limited.
Concerned with the design potentials of using textiles in hospital interiors, the purpose of the PhD project has been to explore the possibilities and design qualities of using these materials in hospital design. Relating to both technical and aesthetic aspects of using functional textiles in hospitals, the project proposes an integrated model that accentuates these design qualities and progress the development within the field of hospital interior design.

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